AIR&SPACE

Smithsonian • February/March 1990

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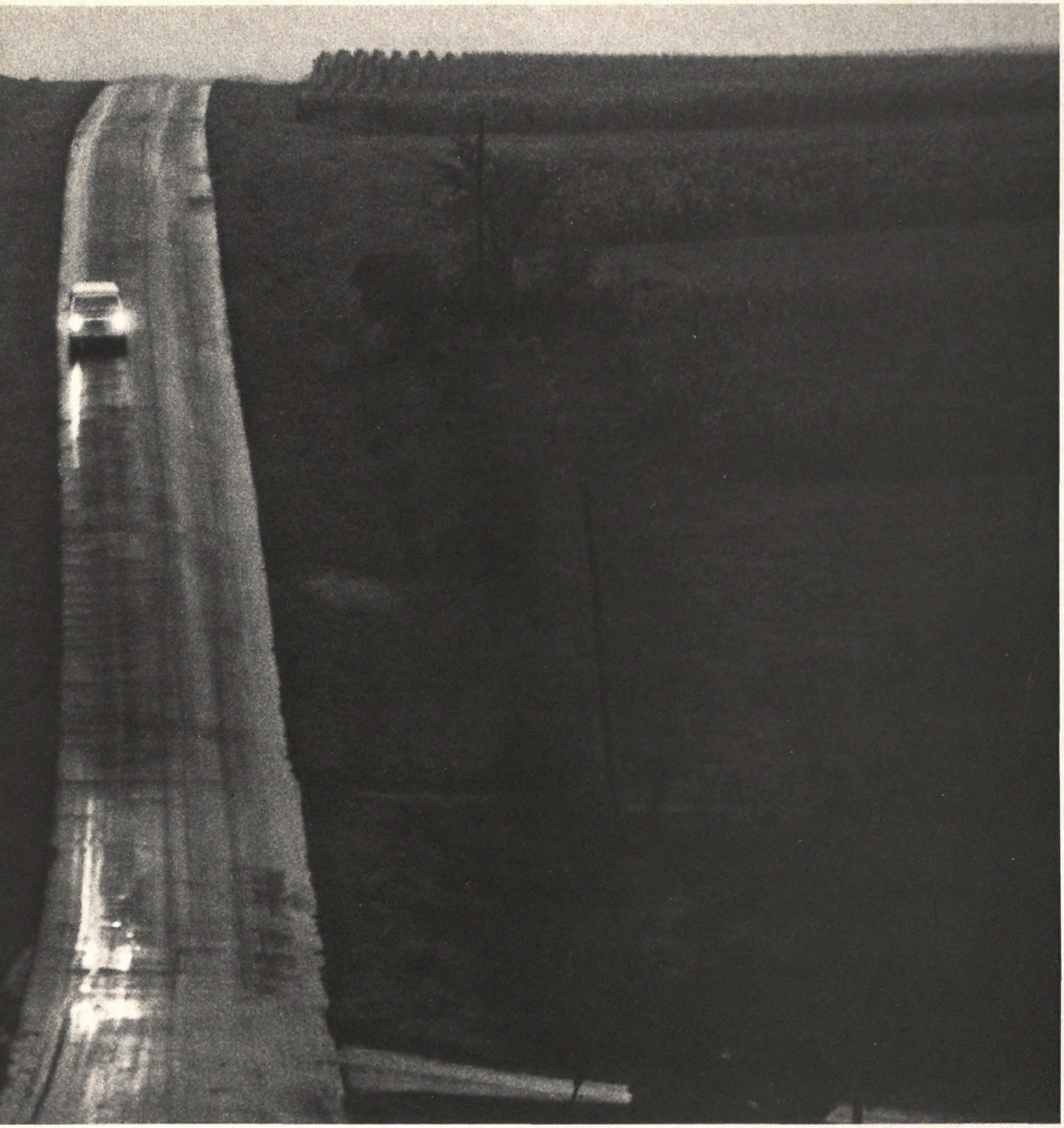

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Volume 4, Number 6

AIR&SPACE
Smithsonian

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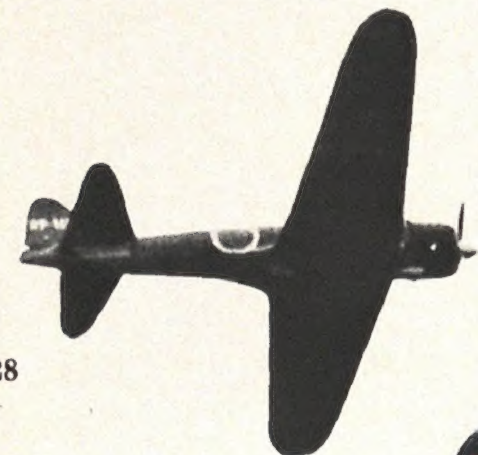

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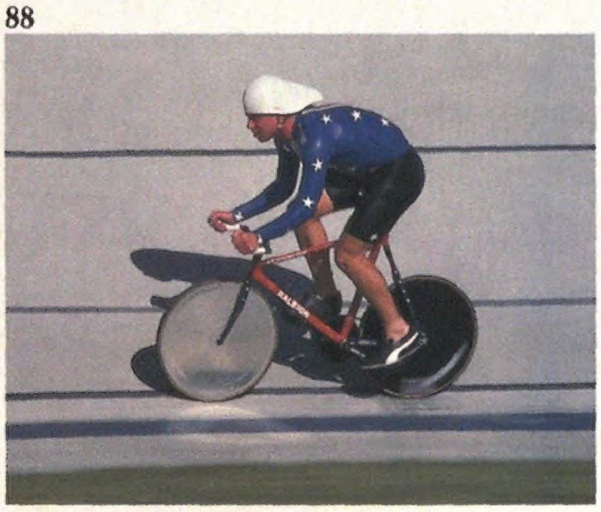

Cover: *Photographer Frank B. Mormillo shot the F6F Hellcat and Mitsubishi Zero from the Planes of Fame Museum in Chino, California.*

AIR & SPACE/Smithsonian (ISSN 0886-2257) is published bimonthly by the Smithsonian Institution, 900 Jefferson Drive, Washington, DC 20560. Subscription price: $18 a year in U.S. possessions, $24 elsewhere. Eighty-five percent of dues is designated for magazine subscription. Single-copy price: $3.50. Second-class postage paid at Washington, DC, and additional entry points. Editorial offices: 370 L'Enfant Promenade SW, 10th Floor, Washington, DC 20024. Advertising and circulation offices: 420 Lexington Ave., New York, NY 10170. Members: Address all subscription correspondence and change-of-address information to P.O. Box 53261, Boulder, CO 80322-3261. Postmaster: Send address changes to *AIR & SPACE/Smithsonian*, P.O. Box 53261, Boulder, CO 80301-3261.

From 1492 to 2492

Two years from now America will celebrate the 500th anniversary of Christopher Columbus' first voyage to the New World. In commemoration of that event, the National Air and Space Museum is planning an exhibition—"Where Next Columbus?"—that will look at the centuries ahead and place the future of space exploration into the clearest perspective allowed by current knowledge.

Most youngsters (and, for that matter, most adults) learn about voyages of the future through science fiction. While science fiction is sometimes remarkably prescient in its vision, lay readers often have difficulty judging where the science stops and the fiction begins. "Where Next Columbus?" will attempt to winnow out the fiction and take a hard look at the kinds of problems we will have to solve if long-distance human space exploration is ever to become a reality.

Such an endeavor must first look at the limitations imposed by nature. Einstein's theory of relativity tells us that we will never travel through space faster than the speed of light. This is only the most obvious constraint we cannot overcome. Others arise from the structure of the universe, the large distances separating planets, and the vast stretches that would have to be traversed to reach the nearest stars, let alone the nearest galaxies similar to our Milky Way. Even at the speed of light, we would need to travel two million years to reach the Andromeda Nebula, our nearest neighbor and Milky Way twin.

We will also need to investigate the workings of the human body before we embark on interstellar journeys. Can we arrest aging, or at least delay it? Can humans survive the incessant cosmic ray bombardment to which any traveler is exposed on venturing beyond Earth's shielding atmosphere and magnetosphere? Even on shorter journeys to the planets, can we halt the muscle atrophy and bone calcium loss that occur in the absence of gravity?

Then there are the sociological problems posed by long-duration flights. How can we ensure that half a dozen crew members, encapsuled in a small spaceship, will not get intolerably on one another's nerves? The French philosopher Jean-Paul Sartre's play *No Exit* portrays hell as a small group of people eternally enclosed in the same room. The experiences of scientists confined to the South Pole station over the long winter can only begin to tell us what we need to know about such a situation.

If we overcome the medical and sociological problems and succeed in traveling across interstellar distances, what can we expect if we encounter living beings of other kinds? History tells us of horrible ravages after explorers exposed native populations to microorganisms against which they lacked immunity. Recall that the first Apollo crew returning from the moon was quarantined for several weeks as a precaution against possible contamination. Is our historical experience at all relevant to the case of possible exposure to organisms evolved in a totally alien biota?

Such dangers suggest that we might first want to learn about occupants of distant worlds through unmanned observations, or better yet, through communications with intelligent beings that might be out there. NASA is now making a major investment in a project called Search for Extraterrestrial Intelligence (SETI), which is designed to look for artificially generated signals from nearby regions of the Milky Way. Detecting and recognizing such signals as intelligent will not be easy, but if other civilizations produce broadcast radio signals with the same abandon as we do, then we should be able to detect some of those signals with sensitive radio telescopes. If we do stumble on a recognizable message, it would be the ultimate cryptographic challenge.

As we continue our voyages into space, we face obstacles as formidable as those overcome by Columbus—enormous distances, daunting transit times, intimidating perils, and staggering cost. "Where Next Columbus?" will examine the challenges our children and theirs will face in the centuries ahead.

—Martin Harwit is the director of the National Air and Space Museum.

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Letters

Solar System?

Ben Bova's "To Mars and Beyond" (October/November 1989) failed to mention the cheapest, most efficient, and most practical propulsion system for a Mars mission, and in this he is not alone. Perhaps it's just too simple, too obvious, but despite favorable studies by JPL and Rockwell, all references to this system seem confined to occasional papers in technical publications. For whatever reason, solar thermal rockets have been all but ignored since their invention in the mid-1950s.

STRs use concentrated sunlight to directly heat a propellant (usually hydrogen, though almost anything will work), and with recent increases in concentration capability, they can achieve specific impulses comparable to electric propulsion systems without having to convert the sunlight into electricity. In addition, their thrust is adequate for a one-tenth to one-hundredth G acceleration, which is higher than electric engines can achieve. In effect, STRs are fusion rockets that can leave their reactor (the sun) a safe distance away and let it broadcast its power to them.

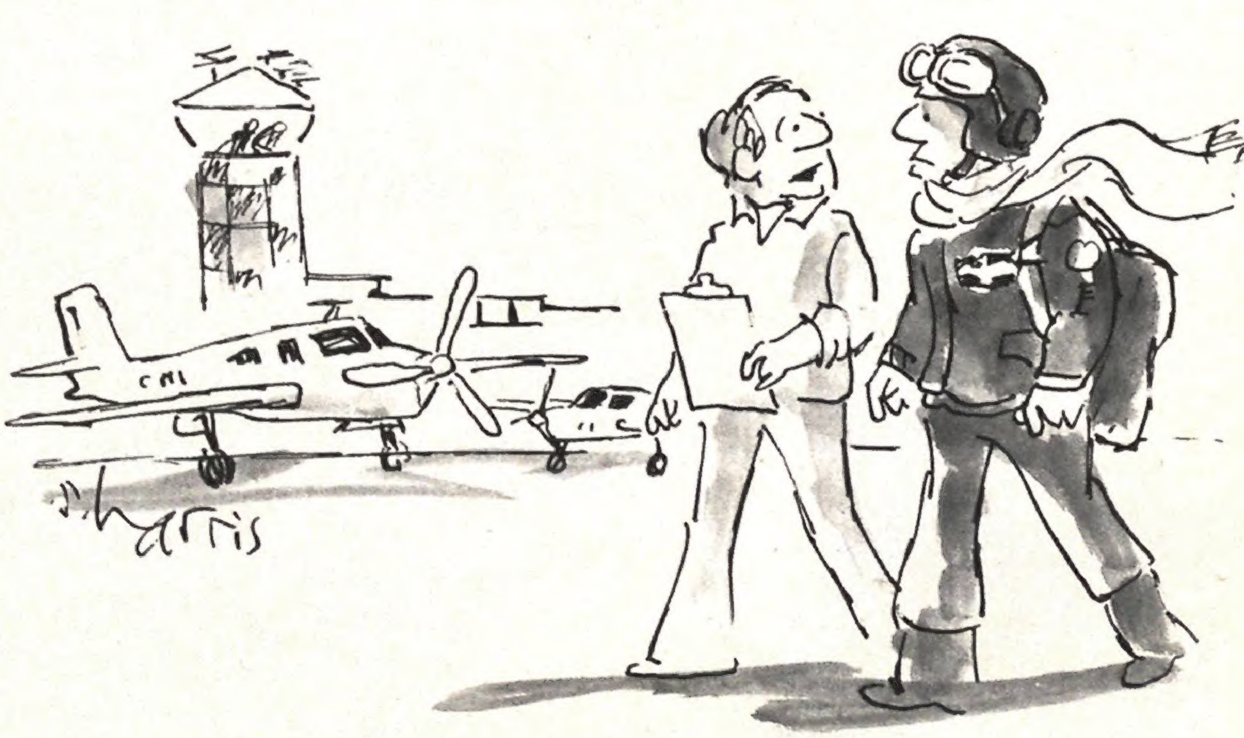
With STRs, a Mars trip could be shortened to a month or so each way, making prolonged weightlessness, isolation, and expendables far less of a problem. STRs could make travel beyond Earth orbit routine and inexpensive—if we can catch the vision.

Steve Mickler
Lithonia, Georgia

I read "To Mars and Beyond" with great interest, but the description of the various possible propulsion systems lacked sufficient depth to satisfy my curiosity. In the event that a fusion power system is developed, would the nuclear-pulse rocket design necessarily be the best one? What about the plasma thruster? It is an electrical rocket, but surely a fusion reactor could be incorporated into this design. Which is more efficient, nuclear-pulse or plasma? Which is more practical?

Matthew DeBell
Woodside, California

Ben Bova replies: Fusion power could be applied to space propulsion in three basic ways: (1) a fusion reaction could generate electricity to drive a plasma thruster; (2) heat from the fusion process could be used to heat a propellant; or (3) the products of the fusion reaction could themselves be



"Is this your first flying lesson?"

used as a propellant to provide thrust. Since no one has yet produced a workable fusion reactor it is too early to say which method might be the most efficient or useful.

Inflated Expectations

While I enjoyed Richard Aellen's article on the autogiro ("The Autogiro and Its Legacy," December 1989/January 1990), I believe he only showed part of the picture. There is no denying the significant roles played by both Cierva and Pitcairn in the development of technology that led, ultimately, to practical helicopters. However, the case has been made elsewhere (*Airpower Journal,* Fall 1988) that one reason behind the rapid decline in popularity of the autogiro was Cierva's exaggerated claims of its potential. When his hopes for payload capacity, cost per vehicle, and other performance measures became clearly unrealizable, interest in his invention quickly waned. Articles written just after Cierva's death in 1936 were noticeably pessimistic about the possibilities of achieving his claimed performance and solving some of the autogiro's other problems. This decline in wide support began prior to Sikorsky's helicopter demonstration, though it was certainly hastened by it.

Cierva and the autogiro are an interesting case study in the way clever and innovative technology can be oversold, to the detriment of both the vehicle's own potential and the development of other alternatives, not to mention the effect on potential users with inflated expectations.

L. Parker Temple III
Burke, Virginia

Shared Experiences

I read the book review of *High Honor* (Reviews & Previews, October/November 1989) with great interest. As a young naval aviator, I shared many of the experiences described in the review. I was a member of VB-2, flying from the USS *Hornet* in 1944. Until only recently I have been reluctant to discuss my experiences with even my family and close friends.

While on the *Hornet* we operated in the same task group as the USS *Yorktown,* on which Lieutenant Oliver Jensen was then conducting interviews with officers and men of the fleet. Details of those experiences were incorporated as part of a wartime publication, *Carrier War,* published in 1945. My copy is tattered, but it brings back memories of dramatic events. I'm

looking forward to reading *High Honor:* perhaps I'll find that I share a common bond with some of those who were interviewed for the book.

Billy Bush
Santa Rosa, California

The Japanese Are Coming!

At the time of "The Battle of Los Angeles" (Above & Beyond, December 1989/January 1990) I was a carrier for the *Los Angeles Times.* The first edition of the paper that day was delayed so that a supplemental first page could be added. I kept a copy of this supplement. The headline, in huge, bold print, read "LA Area Raided." The article stated that foreign aircraft had been in the air and that "At 5 a.m. the sheriff's office announced that an airplane has been shot down near 185th Street and Vermont Avenue. Earlier, the Fourth Air Force in San Francisco said that at least one plane had been downed in the raid."

A fellow carrier told me that, according to an aunt of his who lived near 185th and Vermont, a plane had crashed near her house but the Army quickly removed the wreckage and cleaned up the area.

It's interesting that the supplement did not come with later editions of the *Times,* nor was there any reference to the previously reported downed plane in these editions.

Some years ago, an Air Force officer told me that there were planes in the air over Los Angeles on the morning in question, but they belonged to the United States.

John E. Seidel
Pacific Grove, California

Tom Swafford's "The Battle of Los Angeles" brought back memories for me. I was an Aviation Cadet (that's what we were called in those days) stationed at Santa Ana. On the night of the invasion I pulled guard duty, my armament consisting of a 1903 British Enfield rifle and one cartridge.

The Officer of the Day was a brand new lieutenant fresh out of officer candidate school. He, like the rest of us, had been told that Laguna Beach nearby was the perfect spot for an amphibious landing by the Japanese. When the searchlights lit up and the firing began, he started to scream, "This is it—the invasion has begun!" He came up to my post and asked what I intended to do. Without hesitation, I informed him that I was going to throw down the damned rifle and head east as fast as I could. He agreed that that was the proper course of action, but advised me to spread the alarm as I ran. Fortunately, the alert ended before I could take flight.

William L. Springer
New Orleans, Louisiana

Additions to the Fleet

"Flying at the Bottom of the World" (December 1989/January 1990) neglected to mention that Antarctica's McMurdo Station is served by jet C-141 Starlifters in addition to the NSF's Hercules fleet. I saw both aircraft during stops at Tafuna Airport (Pago Pago International) when I was stationed at a NOAA environmental observatory in Samoa. The C-141s don't

continue to the Pole; besides the damage their jet blast would do to the skiway there, I don't think they have skis. Both McMurdo and Amundsen-Scott (the South Pole) close for the winter when the temperature drops below −55 degrees Fahrenheit, evidently because of the airplanes' hydraulics. However, a winter airdrop has been started and a reliable satellite telephone service has been added.

Roger A.C. Williams
Denver, Colorado

Back in the Future

You've overlooked an even more likely fate for the Voyagers ("Goodbye, Voyager," December 1989/January 1990). In perhaps a century or two, we will speed out to retrieve them. Then those "other spacefaring species" can come and marvel at our 20th century reach and vision in the National Air and Space Museum.

James R. Gandy
Sparks, Nevada

Nuts!

In the October/November 1989 issue a line in "The Blue Collar Spacesuit" puzzles me. Near the end of the story, an astronaut "threaded a bolt on the end of a no. 6 screw." Was this a misprint or is space nutless?

Alan McPherson
The Sea Ranch, California

Corrections

The December 1989/January 1990 Calendar stated that Galileo discovered four of Jupiter's moons on January 7, 1610. On January 7 the astronomer spotted *three* Jovian satellites. He detected the fourth on January 13.

In "Big" (August/September 1989), Richard Martin was misidentified as Robert.

And the winner is . . .

Chris Nowicki of Seattle, Washington, is the winner of *Air & Space/Smithsonian*'s reader survey drawing. He receives a lifetime membership.

Air & Space/Smithsonian *welcomes comments from readers. Letters must be signed and may be edited for publication. Address correspondence to* Air & Space/ Smithsonian, *370 L'Enfant Promenade SW, 10th Floor, Washington, DC 20024.*

Challenger's Prime-Time Portrayal


ABC-TV

Four years after the shuttle *Challenger* exploded, killing its crew of seven, the ordeal will be reenacted in a TV docudrama that has angered some of those closest to the tragedy.

Filming of ABC's three-hour *Challenger* movie began at the Johnson Space Center in Houston last June. By then the controversy had already erupted.

"Why do we have to relive this?" asked Jane Smith, widow of *Challenger* pilot Michael J. Smith, in the *Houston Chronicle* last spring. "Why don't they leave it alone?"

Mission specialist Ellison Onizuka's widow, Lorna, was also distraught. "We don't have a legal right to stop them," she told the paper. "My husband and the rest are public figures and public domain, and I understand that. But my children and I are not public figures. Our lives are private."

Onizuka claimed the script makes her husband appear "dumb" and gives the impression he was selected as a crew member because he was a minority. Smith said the original script changed her daughter Erin to a son. Ronald McNair's widow joined Smith and Onizuka in protesting the movie.

Lisa Turner of the Challenger Center in Houston said the movie "inaccurately portrays the people" involved. Onizuka, her lawyer, and Smith urged writer and executive producer George Englund to drop the project. Backed by ABC, he announced that the movie would proceed.

Most of the story focuses on the lives of the astronauts and their families. Heading the cast is Barry Bostwick as mission commander Francis Scobee. Karen Allen plays schoolteacher Christa McAuliffe, and Lane Smith (Richard Nixon in ABC's *The Final Days*) is Lawrence Mulloy, manager of NASA's solid rocket project and the apparent villain. Another prominent figure in the drama is Roger Boisjoly, the Morton Thiokol engineer who warned NASA of the dangers of a cold-weather launch; he is played by Peter Boyle.

Neither the center nor the astronauts' families will comment further on the movie as its February premiere approaches. ABC's head of movies and miniseries, Allen Sabinson, insists it is a "heroic and uplifting story," filled "with the best of intentions." Englund says he can "understand any feelings the families might have. I did my best to get it right and be accurate. My hope always was that . . . they would feel that it was a good thing, that it was accurate and that it would be something for the archives of their lives as well.

"It's a tremendous event, it seems to me. Great nations and great cultures—they take such events and memorialize them. The laureates of the land either write an opera or poem, or in this part of the century, make a television drama about it."

That may be poor consolation for those reliving the loss of the shuttle against their will. In the *Chronicle,* Turner quoted Erin Smith as saying, "I don't want to see anybody else be my Daddy." Born in the age of the docudrama, she has little choice.

—*Rick Marin*

DAVID HISER

Skiers in Aspen, Colorado, get a lift from Ski Wings, created by entrepreneurial skier Dave Toland of Santa Fe, New Mexico. The nylon panels, which attach to the user's waist and ski poles, slow a downhill run but also offer better control, reduce stress on the knees, and add a little color to the slopes.

Legal Eagles

Modern attorneys, like many physicians, are specialists. Last October a group of lawyers who specialize in aviation law gathered in a Virginia suburb of Washington, D.C., to learn how the law and the courts that serve it are changing. The Eighth Annual National Institute on Litigation in Aviation conference was sponsored by the American Bar Association as part of its members' continuing education. Over 150 participants gathered for the two-day session, during which case law and new legislation were reviewed and tips were imparted on how to win lawsuits.

The conference culminated in an afternoon-long mock "mini-trial." These scaled-down hearings, a relatively recent development, are aimed at relieving congested court calendars. The jury may number six or nine instead of 12 and a time limit is imposed on attorneys at every stage of the trial, from jury selection to closing arguments. For the mock trial, attorneys argued the case and jurors (some of whom were law students) rendered a verdict. But that's where the verisimilitude ended.

The case involved an imagined scenario in which a Cessna Skyhawk, ordered by the control tower to taxi into position for takeoff, was struck from behind by a commuter airliner landing on the same runway. The plaintiff, one "Constance Sitanwait" (played with considerable gusto by Constance Wilds, an official with the Ninety-Nines women pilots' organization), was suing the Federal Aviation Administration and the commuter airline. The trial setting was Tennessee, where a very real law says that any contributory negligence on the part of the plaintiff rules out any recovery at all. The outcome hinged on whether the FAA and the airline could convince the jury that Sitanwait, while sitting and waiting in her Cessna, contributed to the accident.

Although this was a mock trial, no attorney worth his salt likes to lose, and both sides argued with passion. In his opening statement, Joseph T. Cook, a California lawyer representing the plaintiff, described the runway collision as "a simple case . . . a traffic accident" similar to that of automobiles on an interstate on-ramp. He depicted Sitanwait (whom he assisted to her seat with some tongue-in-cheek drama) as a victim who "didn't do anything wrong."

Janine Simerly, a San Francisco trial attorney, opened for the commuter with some tough talk. Calling Sitanwait an "inattentive pilot," Simerly pointed out that every pilot has command responsibility for his or her airplane. Sitanwait, she argued, "began playing the role of spectator." Steven J. Riegel, a Department of Justice attorney in Washington, agreed in his argument on behalf of the FAA, saying Sitanwait "failed miserably in those [command] responsibilities."

Cook emphasized Sitanwait's experience, her accident-free record, and her compliance with the rules. In cross-examination, Simerly bored in on Sitanwait's lack of "vigilance," and Riegel built on that, bringing up a four-minute interval on the runway during which there'd been no communication with the tower (a pilot who discovered a snake on board was said to have distracted the tower crew during that period), a situation, he pointed out, that should have made Sitanwait "uncomfortable."

In closing, Simerly lashed out at an American attitude that an accident is always "someone else's fault" and emphasized individual responsibility. Riegel described the plaintiff's case as an "extreme position . . . that her contribution [to the accident] is exactly zero."

The jury retired to ponder the case in a room with a video camera linked to the classroom. The three male jurors sat opposite the three females (a configuration that occasioned a question—"just coincidence," they agreed), and the group split: the men generally for the plaintiff, the women having no sympathy for her position and basically taking no prisoners.

Lawyers worry about mini-trials because of the restricted time allotted to developing a case and educating juries. In a paper entitled "Mini-Trial? Mickey Mouse!" that appeared in the proceedings, Cook argued, "A trial is not like a wind tunnel. You can't use a miniature and get the same data" (Simerly later said she agrees with him). "I think it stinks," Cook snorted in print. And when the jury finally voted, Cook and his client had lost.

—George C. Larson

Update

TIGHAR Takes on Earhart

Though the Nungesser and Coli mystery is still unsolved ("The Search for L'Oiseau Blanc," February/March 1988), the International Group for Historic Aircraft Recovery has also taken up the Amelia Earhart case. Last September a TIGHAR team spent three weeks scouring the Pacific island of Nikumaroro, which project director Richard Gillespie considers "the most likely place for the Earhart flight to have ended." The TIGHAR team recovered aluminum artifacts and a cigarette lighter; the items are are now being evaluated.

"How Much Can You Carry?"

Charles Gallagher parked his Beechcraft Bonanza at Oakland Airport's North Field on Tuesday, October 17, and started the drive home to Marin County. He got on Highway 880 North, drove through the elevated double-deck Cypress structure, and headed toward San Francisco's Bay Bridge. The time stamped on his toll receipt was 4:59:44.

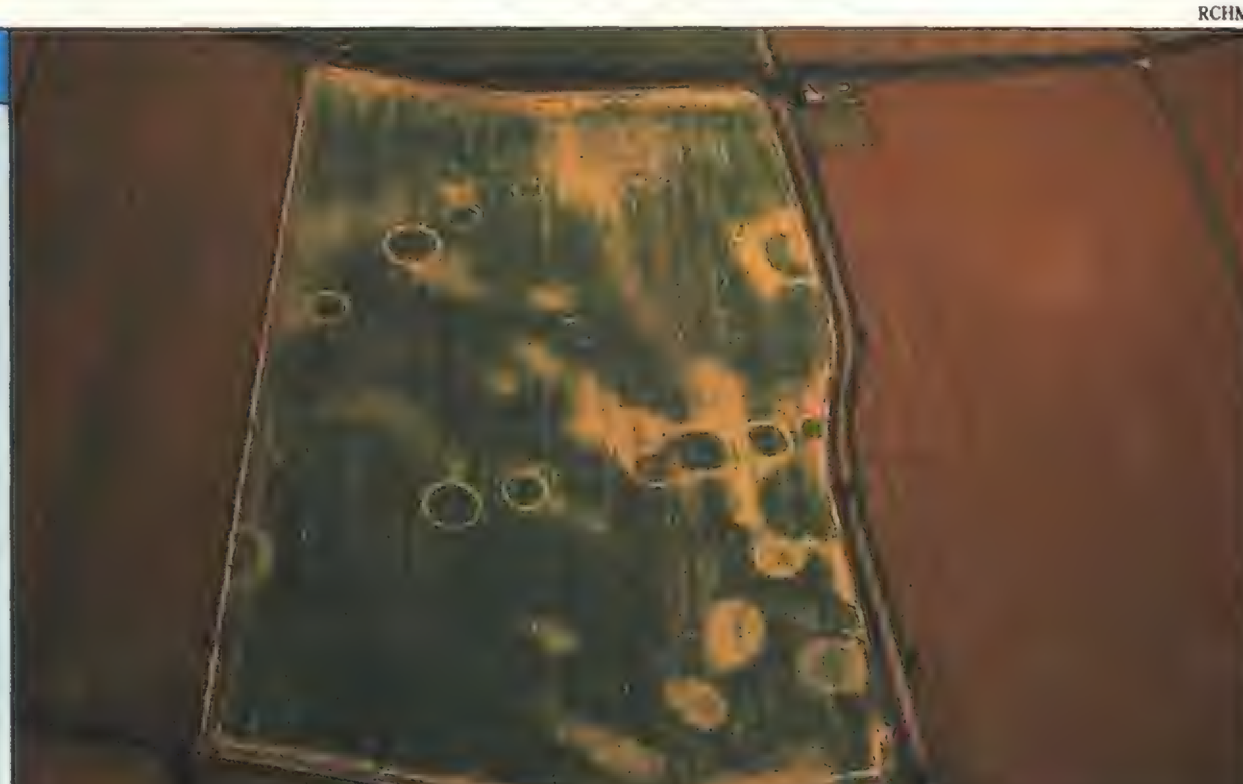
Gallagher was accelerating onto the bridge when the 7.1-magnitude earthquake struck at 5:04—the strongest to hit

Update

Aerial Archeology

After Great Britain's hot, dry summer of 1989, the staff of the Royal Commission on the Historical Monuments of England was able to locate numerous ancient sites from the air ("Looking Down on History," August/September 1988). Pictured are the remains of a cemetery near Witchampton, Dorset, containing Bronze Age (c. 1500 B.C.) burial mounds. The graves have been obliterated by centuries of plowing, but their circular ditches survive beneath the soil.

RCHME



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LARRY E. JOHNSON

The propane burners of more than 350 hot-air balloons lit the landscape at the Albuquerque, New Mexico International Balloon Fiesta last October. The 18th annual gathering drew a total of 520 balloons and 1.2 million spectators.

California in over 80 years. "At first I thought I had a flat tire," he says, "so I pulled over to the side to check, as everyone else did. Then we all realized it was an earthquake."

At the time, Gallagher, an aviation insurance broker, didn't know that a section of the Bay Bridge had buckled just ahead of him—nor that the Cypress structure behind him had collapsed, killing 42 people and injuring 52. Not knowing what to expect up ahead, he turned around and found an alternate route home, and only when he turned on the news and heard about the freeway collapse did he realize how lucky he'd been.

"For the next couple of days I walked around in a funk," he says. "I couldn't focus on my work or anything else." Like thousands of Bay area residents who were relatively unscathed by the catastrophe, Gallagher had what psychologists call survivor's guilt. To assuage it, he had to do something to help the victims.

News trickled in from outlying areas. Downtown Santa Cruz, close to the epicenter, was demolished. Watsonville, "Artichoke Capital of the World" and home of the annual Watsonville Antique Fly-In, had a contaminated water supply, no electricity, impassable roads, and more than 2,000 residents suddenly without homes.

On Thursday, Sonic Communications, a cable distribution company in Walnut Creek, decided to send paychecks to its Watsonville facility in a private aircraft. Company officials offered the extra space on board to the Contra Costa Food Coalition. Watsonville's most desperate need was for water, and Sonic's airplane delivered 50 gallons. Word got out, and pilots all over the Bay area volunteered their airplanes and services. The next day the coalition loaded 40,000 pounds of food, water, and clothing into dozens of private aircraft waiting at Concord's Buchanan Field. And at San Jose's Reid-Hillview airport, pilots were organizing weekend flights to carry food, blankets, and camping equipment to the stricken town.

Gallagher heard about the airlifts and saw a way out of his depression: he would organize a lift from Marin County. He'd provide the pilots and the Marin Food Bank would provide the supplies. A few calls triggered a huge response. "There was some talk about getting United Airlines to donate a 727 to do the lift," he says, "but that wouldn't give many people a chance to help."

On Sunday morning some 50 aircraft arrived at Hamilton Army Airfield in Novato, the only Marin County airport with an adequate staging area. The standard greeting at Hamilton was "How much can you carry?" Trucks pulled up with pre-weighed boxes of canned tuna, fruit, and vegetables. Volunteers carried plastic bags full of toilet paper and paper towels. One by one the airplanes took off for the one-hour flight, bunching up in groups of five to ease the strain on air traffic control facilities. When the airplanes arrived at Watsonville Municipal, food bank workers gathered up the goods as they were unloaded. One pilot, who'd just delivered 300 pounds of supplies in a Cessna 182 he rented for the occasion, took a moment to reflect. "It feels good," he said. "It feels real good."

—Elaine de Man

Update

C-5s on the Rocks

C-5 Galaxys have joined the fleet of transports that serve Antarctica missions ("Flying at the Bottom of the World," December 1989/January 1990). Last October two C-5s, loaded with passengers, cargo, and four helicopters, landed on McMurdo Station's ice runway. The C-5s allowed a head start on the season's missions; previous helicopter shipments were on a "some assembly required" basis.

Lunar Laser Tag

Nearly every day astronomers at McDonald Observatory in west Texas aim a series of lasers at reflectors on the moon and try to measure the flashes of returning light. They've had 20 years of practice, and they've gotten pretty good at it. The Laser Ranging Retro-Reflector measurements began two weeks after the Apollo 11 landing and are still providing data on the orbit and structure of the moon as well as geophysical information about Earth.

In July 1969 Neil Armstrong and Buzz Aldrin placed an 18-inch-square array of fused silica cubes near their lunar module. The crews of Apollo 14 and 15 left another two reflectors in 1971. (Soviet Lunokhod 1 robotic rovers positioned two reflectors in the early 1970s, but only one functioned and its design did not provide highly accurate measurements.) The reflectors' simplicity and the moon's lack of both an atmosphere and significant seismic activity allow the experiments to continue today. Initially there was concern that dust would gradually coat the reflectors, "but there's been no measurable decay in 20 years," says Harlan Smith, a University of Texas astronomer and the former director of McDonald.

CHARLES E. BEYL

Getting the beam to hit the reflector has been likened to training a rifle on a moving dime two miles away, even though the beam's diameter expands to a couple of miles on its quarter-million-mile journey. The beam expands even more as it speeds Earthward, but only a few of the sextillions of outgoing photons in each pulse find their

way back to the emitting telescope, and that tiny flicker must be detected against the wash of moonlight. At 10 shots per second for up to 30 minutes, only about one in 1,000 yields usable data. "It's probably the most inefficient experiment ever devised," says Smith, "but oh boy, do you wring out that one photon."

Before the experiment began, scientists had the moon's location pinned down to within a mile. The first laser pulses were about three nanoseconds long, which limited measurement accuracy to one or two feet, but the use of shorter laser pulses along with other improvements has brought more precise measurements. Peter J. Shelus of the University of Texas, who has directed the project since 1982, says, "Right now everyone feels we're at the centimeter level." Eventually the use of two laser beams operating at different wavelengths should bring accuracy to within millimeters.

Using the moon as a reference point, the measurements also chart Earth's crustal movements and note the degree of "polar wobble" caused by the planet's interior activity. The findings also apply to lunar physics, solar system dynamics, and lunar and terrestrial geodesy and rotation rates.

The program, which was brought up to speed and directed by Eric Silverberg of the University of Texas for its first 13 years, was originally designed to test two competing theories of relativity. Twenty years of increasingly precise measurements of the lunar orbit show that Einstein's general relativity theory is the most solid. "So," says Smith, "Uncle Albert wins again."

—Hank Hogan

Update

Da Vinci III Airborne

California Polytechnic State University students achieved a major victory last December 10 when their human-powered helicopter hovered "above shoe-top level," according to a school spokesman ("Hover Story," June/July 1988). The Da Vinci III attained an altitude of about eight inches for eight seconds. A craft must hover for one minute and reach an altitude of three meters (about 10 feet) to win the $20,000 Human Powered Helicopter prize.

DoD

The shuttles have to land at Edwards Air Force Base on good days and bad.

Oh Say, Can You See?

"I was first here in about 1969 and the visibility was darn near perfect," says John Hoffman, the vice commander of California's Edwards Flight Test Center who has logged nearly 3,000 hours as a test pilot. The Mojave Desert, with outstanding visibility and weather over its wide open spaces, was originally prime test flight real estate where military bases put down roots. But in the 1940s air quality started to decline. "Our visibility has dropped on an average from 50-plus miles down to 33 miles," says Hoffman. "We have canceled missions strictly due to low-visibility conditions. I'd say about five percent . . . and it's going to get worse."

Dirty air interferes with the filming of flight tests, which lose much of their value without clear photographic documentation. "The other real danger," says China Lake Naval Weapons Center chief test pilot Fred Lentz, "is that it really cuts the visibility to see other planes. That detracts from the test because you're more worried about other airplanes in the area."

Project RESOLVE (Research on Operations Limiting Visual Extinction), a two-year defense department study issued in the summer of 1988, found that 75 percent of the Mojave Desert's air pollution

is man-made. The San Joaquin Valley contributes two-thirds of the dirty air, with the remainder split between the Los Angeles basin and local sources.

RESOLVE cites fossil fuel sources—diesel and gasoline vehicles and equipment, Bakersfield's petroleum industry—as the major contributor to reduced visibility. In 1979 proposals to build two coal-fired electrical plants in the Antelope Valley north of Los Angeles—later turned down—focused military attention on the problem. Backed by the California Air Resources Board, commanders in the R-2508 Restricted Airspace area (which includes NASA's Ames-Dryden facility, George Air Force Base, and the Fort Irwin Army training center) created a visibility protection program similar to but broader than one in effect at Lake Tahoe. China Lake's John O'Gara, the current program manager, says that if state and federal clean-air standards were achieved the problem would be lessened—but would not disappear. "It doesn't take a great deal of material in the atmosphere to reduce visibility dramatically," he says. This June, Cliff Calderwood, a Kern County air pollution control manager, plans to propose to the local air pollution board regulations on particulate matter of 10 microns or less—"about one one-hundredth the width of a human hair," he says.

O'Gara notes that in a one-year period that ended last March, nearly 50 percent of missions from Edwards, where the visibility loss is the worst, "reported some degree of image obscurity." The conditions will get worse as urban sprawl continues in the Antelope Valley. "We may find ourselves [having] to schedule flights in response to the environment rather than the acquisition and procurement schedule," O'Gara says.

—Bob McCafferty

Update

Commercial Launch Fails

Space Services' second suborbital launch failed shortly after liftoff last November 15 (Soundings, June/July 1989). The Consort 2 booster, carrying 12 microgravity experiments, began wobbling four seconds into the flight. The second stage ignited but shut down 18 seconds later. The payload canister parachuted to a landing within a mile of the White Sands Missile Range launch site in New Mexico.

Anniversaries . . .

GEOFF CHESTER

The Lowell Observatory in Flagstaff, Arizona, was founded by Percival Lowell.

1855
March 13 Astronomer Percival Lowell is born in Boston. Although Lowell made many planetary observations and contributions to astronomical photography, his work has been overshadowed by his erroneous belief in the existence of a canal irrigation system on Mars built by intelligent beings.

1910
March 8 Baroness Raymonde de Laroche becomes the first woman to receive an airplane pilot's certificate. To win her license, de Laroche completed the necessary test flights and landings before an audience of Aero Club of France officials at an air meet in Cairo. When asked upon landing if it was unsafe for a woman to fly an airplane, de Laroche said, "It does not rely so much on strength as on physical and mental coordination. Most of us spread the hazards of a lifetime over a number of years. Others pack them into minutes or hours. In any case, what is to happen will happen." Nine years later she died in an airplane accident.

1926
February 4 The German Air Service Company shows the American silent film *The Lost World* to passengers in an airplane flying over Berlin. Music broadcast from a Berlin radio station accompanied the movie. The in-flight showing of the 1925 film, a depiction of an Arthur Conan Doyle adventure story, was the first one for a German audience. After this initial success, the airline announced its plan to install film projectors in many of its airplanes so that passengers, especially those traveling at night, would not grow bored.

1929
February 4 A Lockheed Air Express takes off from Los Angeles at sundown in an attempt to fly nonstop to New York for an airshow. Lockheed had hired Army reserve captain Frank Hawks to ferry the red and silver monoplane to the East Coast, but since the Air Express' two wing tanks could not carry enough fuel for a transcontinental run, someone had to accompany Hawks and manually pump gas from cans stored in the airplane's cabin. Lockheed chose Oscar Grubb, an aircraft assembly superintendent, who just before takeoff slithered his way into a cabin packed with 75 five-gallon tins of Texaco aviation gasoline. Midway through the flight the engine began to sputter and then quit entirely as Hawks switched from tank to tank. When the alarmed pilot peered into the cabin he saw Grubb sprawled on top of a pile of gas tins, fast asleep. Hawks yelled, "Hey Oscar! Oscar! Give her some gas or get ready to jump!" Grubb awoke in a panic and started pumping gas, which soon revived the engine. When the Air Express finally landed at Roosevelt Field after an 18-hour flight, a semi-conscious Grubb, sickened by turbulence and gas fumes, tumbled out of the airplane and proclaimed, "Never again, not for a million dollars." Hawks helped him up and told reporters, "Here's your real hero. He's the one who made it possible."

Raymonde de Laroche was the first woman to solo in an airplane.

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1936
February 1–9 The Douglas Aircraft Company unveils the Douglas Sleeper Transport at the National Pacific Aircraft and Boat Show in Los Angeles. Thousands of people paid the 40-cent admission fee to get a close look at the DST, which was the show's chief attraction due to its large size and the prestige of its manufacturer. Airlines used the DST to transport passengers across the country in relative luxury: the airplanes were equipped with upper and lower sleeping berths, and hot meals were served on portable tables.

1937
March *Aero Digest* publishes advice for aspiring pilots: "Young man, you're wasting time and bothering busy people if you run to airlines and airplane and engine factories crying hopefully, 'Here I am, as God and the local High School made me.' Preferred to you every time will be the young man who has been trained in some technical aviation school. You can no more expect to start untrained in aviation than you could start untrained and hang up your shingle as a doctor or a lawyer. They don't even want you to 'sweep out the factory'—a job that a lot of boys say they want to start with."

March 2 President Franklin Roosevelt presents the Harmon Trophy to wealthy sportsman Howard Hughes, honoring him as the outstanding aviator for 1936. The International League of Aviators chose

Hughes for the award based on a nonstop transcontinental speed record that he set on January 14, 1936. (Hughes broke his own record a year later.) At a luncheon given in the pilot's honor, E.R. Breech, chairman of the board at North American Aviation said, "I am glad Mr. Hughes deflated speed. Americans expect the impossible, and usually get it."

1941
March 6 Sergeant Floyd S. Beard falls 750 feet to his death, becoming the Army's first parachute fatality. After Beard jumped with 35 members of the 501st Parachute Battalion of Fort Benning, Georgia, his chute failed to billow open. By the time he pulled the rip cord on his emergency parachute, he was too low for it to open.

1969
March 2 Test pilot André Turcat flies the Concorde for 27 minutes over southern France—the supersonic transport's long-awaited first flight. Scores of reporters and onlookers at Blagnac airport watched the Concorde's takeoff, the culmination of seven years' work by British and French companies. Turcat, who became a national hero, told the excited crowd, "It flies pretty well. It was as perfect as we had expected." The historic flight threw all of France into a Concorde craze, with restaurants, stores, and everything from matches to shampoo being marketed with the Concorde name.

1981
March 19 Two hours after a successful countdown rehearsal for space shuttle *Columbia*, a Rockwell technician is killed and four others injured at Kennedy Space Center's launch pad 39-A. The five men had entered a compartment near the shuttle's engines and immediately passed out from hypoxia. Unbeknownst to the technicians, the compartment was being purged with nitrogen—a colorless, odorless gas—to prevent the accumulation of flammable gases around the engines. "We just don't know why the men were in that area while a nitrogen purge was going on," said a Kennedy spokesman. An investigation concluded that lack of communication among work crews led to the fatal accident.

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The publicity-shy Howard Hughes went to the White House to receive the Harmon Trophy.

. . . and Events

February 24–April 8
"Into the Sunlit Splendor: The Aviation Art of William S. Phillips." Smithsonian Traveling Exhibition. At Parkersburg Art Center, Parkersburg, WV, (304) 485-3859.

March 5–7
Upper Midwest Aviation Symposium. Leaders will speak on general aviation topics and hold a job fair. At Radisson Inn, Bismarck, ND, (701) 239-4898.

March 6–9
Professional Aeromedical Transport Association Seminar. A symposium for professionals involved in aeromedical transport. At Hyatt Regency, San Francisco Airport Hotel, (800) 541-7517.

March 20
The vernal equinox occurs at 4:19 p.m. EST, marking the beginning of spring in the northern hemisphere.*

March 30 & 31
Images of Women in Aviation: Fact vs. Fiction. Sponsored by Embry-Riddle Aeronautical University. The conference will investigate the stereotypes of women in aviation careers. Speakers include Jeana Yeager and a United Airlines pilot. At Sheraton Resort and Conference Center, Prescott, AZ, (602) 776-3838.

March 31
Airline Memorabilia Flea Market. Buy, sell, and trade items such as aircraft models, postcards, timetables, pilot wings, and dishware. At Holiday Inn, Dallas-Fort Worth Airport South, Irving, TX, (817) 540-9604.

April 9–12
United States Space Foundation's National Space Symposium. At Broadmoor Hotel, Colorado Springs, CO, (719) 550-1000.

**Call the Smithsonian's Earth and Space Report at (202) 357-2000 for recorded information on astronomical events.*

Organizations wishing to have events published should submit them four months in advance to Calendar, Air & Space/ Smithsonian, *370 L'Enfant Promenade SW, 10th Floor, Washington, DC 20024. Events will be listed as space allows.*

—Diane Tedeschi

The seats on Douglas DSTs could be converted into sleeping berths at night.

NASM

Flight School

As they keep their eyes glued on a rocket propulsion demonstrator, a handful of youngsters count backwards at the top of their lungs ("*. . . four, three, two, ONE* . . . "). To their delight, the demonstrator suddenly whirls to life, spinning furiously around its axis until it is only a blur of motion.

This countdown happens once a week at the National Air and Space Museum during a new hands-on program called "Forces of Flight." The 20-minute presentation, which focuses on atmospheric flight, is the first of several that will be sprouting up around the Museum in the future. Their aim will be to offer visitors more science about air and space flight.

"When people come to the Museum we want them to understand *why* airplanes fly," says Jan McColl, chief of NASM's office of education. Every day the case for hands-on demonstrations in the Museum is made by visitors who can't resist the urge to touch *Friendship 7,* Gemini 4, and the Apollo 11 command module *Columbia,* even though the space capsules are covered with plexiglass. "It demonstrates people's need to actually feel and touch things," she says.

A "slice" of the moon, taken from a sample brought back by Apollo 17 in 1972, is one of the favorite items in the Museum because visitors are allowed to touch it. But NASM's precious air- and spacecraft, which are part of our cultural and technological heritage, don't lend themselves to hands-on exhibits. Instead the Museum plans to demonstrate technological concepts in a format in which visitors can participate.

Gaping mouths are a common sight during the "Forces of Flight" demonstrations.

CAROLINE SHEEN

"No tricks," Kit Stetser assures a standing-room-only crowd in the Looking at Earth gallery; "you can do this at home." Stetser, a training assistant in the office of education, developed the demonstration and trains docents to present it. Designed for both children and adults, the presentation leans heavily on audience participation and makes the most of the enthusiasm of the youngsters in the audience. "Anytime you get a reaction from a kid it's fun," Stetser says.

The demonstration follows a roughly chronological order from bird flight to rocket propulsion and relies on a handful of simple props. A mechanical model of a bird—an ornithopter—flaps its wings as it flies circles over the audience. A hot-air balloon, which gracefully ascends to the ceiling, shows that heating air causes it to rise. Later a balsa wood glider flies a loop in a lesson about wings.

Each concept of flight is related to a specific aircraft in the Museum. As he launches a miniature wooden propeller with his hands, Stetser explains where the Wright Flyer is located and encourages the audience to see for themselves how its propellers have the same cross-sections as its wings.

The audience claps appreciatively as the demonstration ends. Then the crowd wanders off to see the airplanes and spacecraft—not yet rocket scientists, but perhaps a little wiser about the principles of flight.

Flattops at War

Three decades after an exhibition pilot named Eugene Ely landed a Curtiss biplane on the deck of the USS *Pennsylvania,* the U.S. and Japanese navies fought a battle in which the opposing surface forces never came within sight of each other. This marked the beginning of a carrier war that would last until October 1944 and the battle at Leyte Gulf in the Philippines. In a desperate last stand, Japan would resort to suicidal kamikaze missions.

"Carrier War in the Pacific," a new

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A landing signal officer directs a Hellcat landing on a carrier in the Pacific.

exhibit in the Sea-Air Operations gallery, retraces the war to the Coral Sea, Midway, the Eastern Solomons, the Santa Cruz Islands, the Philippine Sea, and Leyte Gulf. These far-flung islands, atolls, and archipelagos in the south Pacific soon enough became household names to the American public.

The voice of Lowell Thomas booms in the gallery ("One of the greatest blows of devastation ever struck in ocean warfare! Among the losses is the cruiser you see burning there!") as Fox Movietones replay the battles, which were fought in the air as much as on the sea. Gunsights, aviators' suits, and aircraft models are included, but the bulk of the exhibit consists of newsreels, newspaper clippings, maps, and photographs. "There's one thing that we tried to stress all the way through the exhibit: people, on both sides," says E.T. Wooldridge, assistant director for Museum operations.

The U.S. Marines distinguished themselves not only on the beaches but in the air. A film describes the Marines' aviation contribution, especially in the Solomon Islands, where so many ships from both sides were sunk that the waters became known as Ironbottom Sound. Medal of Honor winner Major Joseph J. Foss, a Marine ace who racked up 26 victories, narrates the film.

The exhibit also pays homage to the carrier USS *Enterprise.* Reported sunk six times by the Japanese, the "Big E" participated in 20 battles in the Pacific and was the most decorated ship in World War II. Photographs collected from men who served aboard the *Enterprise* appear on a videodisc.

The hundreds of photographs in the exhibit vividly recall the war in the Pacific, often with graphic realism that is new to the Museum. "We've been criticized in the past for glamorizing war and not showing the bad side of combat," says Wooldridge, explaining the decision to use photographs that portray the horrors of war.

For those who served in the Pacific, the recollections the exhibit evokes will be personal. When Joe Deigh, a lieutenant aboard the *Enterprise* during the war, visited the exhibit, it stirred up many memories. "It's not just photographs," he says, "but you see yourself on deck or running to general quarters . . . ."

—*David Savold*

Museum Calendar

Except where noted, no tickets or reservations are required. Call Smithsonian Information at (202) 357-2700 for details.

New Exhibit "Hughes H-1 Racer." Record-breaking aircraft designed by Howard Hughes displayed with its "speed" wings. Opens February 28 in the Golden Age of Flight gallery.

Film Series Time Travelers Space Fiction Film Series: *Buck Rogers* (1979), February 2; *Time After Time,* February 9; *Unidentified Flying Oddball,* February 16; *Back to the Future II* (tickets: $1), February 23. Langley Theater, 7:30 p.m.

February 3 Monthly Sky Lecture: "Star Laws: What are the Rules in Space?" George Robinson, Smithsonian Institution. Einstein Planetarium, 9:30 a.m.

February 8 General Electric Aviation Lecture: "The Lifting Body Program." Gerald Gentry, Northrop test pilot. Langley Theater, 7:30 p.m.

February 13 Black History Month Lecture: "Blacks in Aviation: A Lesson in History." John Morrow, University of Georgia. Langley Theater, 7:30 p.m.

February 14 Exploring Space Lecture Series: "The Search for Dark Matter in the Universe." Lawrence Krauss, Yale University. Langley Theater, 7:30 p.m.

February 21 Space Science Lecture: "The Hubble Space Telescope." Robert W. Smith, NASM. Langley Theater, 7:30 p.m.

March 3 Monthly Sky Lecture: "Shooting for Saturn: The Wide Field Planetary Camera." Ken Seidelman, U.S. Naval Observatory. Briefing Room, 9:30 a.m.

March 8 General Electric Aviation Lecture: "Barrel Rolls and Figure Eights." Duane and Judy Cole, veteran aerobatic pilots. Langley Theater, 7:30 p.m.

March 14 Exploring Space Lecture Series: "Black Holes." Minas Kafatos, George Mason University. Einstein Planetarium, 7:30 p.m.

March 29 Stealth Bomber Lecture: "From Flying Wing to B-2." E.T. Wooldridge, NASM, and Irving Waaland, one of the original designers of the Northrop flying wing. Langley Theater, 7:30 p.m.

45 More Missions

Manduria, Italy, October 7, 1944. The wake-up corporal flicked on the overhead lights and barked, "Mission is on. Regular briefing 5:30, specialized briefings 6:30." Apprehension descended. Not fear—there had been nothing that frightening about my first five missions as a B-24 bombardier—but I felt some uneasiness.

I dropped my pack on the northeast side of a particular light stanchion before going to breakfast. If another bag had been there I would have moved it—this was my spot. I'd put my equipment there since my first mission and everything had gone okay so far. I also listened to a recording of Duke Ellington's "In a Mellow Tone" at the Red Cross Club the afternoon before each mission. (By the time I completed my 40th, I was so worried that something would happen to the V-disc that I kept it locked in the squadron safe.) I was not alone in my superstitions—one pilot donned a brassiere over his flak vest whenever he approached a target. Another walked backward, guided by a crew member, from the briefing room to the crew truck. Several emulated Spencer Tracy in *Test Pilot* by sticking a wad of gum near the bomb bay doors before climbing aboard.

In the briefing room the intelligence officer, impeccable in starched shirt and tie, stood before a map of Europe. "Gentlemen," he said, "today the entire 15th Air Force will concentrate on oil targets. The 47th Wing will hit the Vienna area." There were low groans and a flurry of cigarette lighting. Two or three people headed for the latrine.

I was petrified. Weeks earlier I'd rushed up to a returning bombardier I recognized from training sessions in Texas. He looked dreadful: grease-spattered jacket, sweat-matted hair, red lines across the nose from an oxygen mask, and dead eyes. "You assigned to this mess?" he asked. "Listen, we just been to Vienna. It was awful. They tell you to go to Vienna, do something else. Tell them you'll pack parachutes or clean latrines. But don't go."

En route to Vienna, I performed my meager duties in a trance. I calculated and recalculated target information and fed it into the Norden bombsight. I strapped on a walkaround oxygen bottle, squeezed into the bomb bay, and pulled the safety pins from the eight 500-pound bombs. I studied the target maps and photos, removed the heated bombsight cover, placed it on the floor for use on the way home, and opened the door to the nose turret overhead so that the gunner could get out in a hurry if he had to.

Crouched over the bombsight, I followed the dirty brown Danube to its confluence with the Danube Canal. There, on a spit of land in the river, was our target: the Winterhaven oil storage depot. On a narrow road behind the depot I saw flashes. Sunlight reflecting off puddles? . . . No, by God, those were gun flashes—88-mm anti-aircraft fire.

"Bombardier to pilot. Someone's getting shot at. Must be—" *KaWHOOM rattle.*

The first burst was right under us. The *rattle* was the sound of shrapnel piercing aircraft skin. Two more explosions followed. Interphone discipline fell apart.

"We're hit!"

"Where?"

"I think we lost some fluid."

"There's holes in the wing."

"Christ! Get us out of here!"

The target slipped away beneath us. We plowed over the heart of the city amid heavy flak. For the first time in my life I knew stark fear. *It always happens to someone else,* I thought, *and now someone else is us.* Another explosion shook the aircraft. The lead airplane dropped its bombs. I hit my toggle switch, shouted "Bombsaway!" and felt our airplane rise, free of its 4,000-pound load. Then came a crushing pain in the back of my neck. The world went white, then black as I felt myself falling.

For a horrifying moment I thought I'd been blinded. Then I realized that my head had slid into the bombsight cover. The crushing weight was the nose gunner, who'd fallen out of the turret and flattened me. The white mist was the pulverized plexiglass of the astrodome, shattered by shrapnel. I assumed the pilot and copilot were dead.

We were in a dive. We'd approached the target at 26,000 feet and were now passing through 19,000. I kicked open the nose gear door hatch and swung my legs out. Below me hell awaited—billowing smoke, an airplane sliding away with white vapor streaming from an engine, flak blossoming like drops of black paint flicked on wet paper.

Glancing up, I saw the pilot's feet kicking furiously at the rudder pedals. *Good old Bert,* I thought. *He's still alive and trying to pull us out of this. I'll sit here until we pass through 12,000 and then jump.*

But I couldn't relay this decision to anyone—the interphone cords had been disconnected. And everyone wanted out. The navigator was pushing me with his feet and the nose gunner was pushing the navigator. I resisted by catching hold of the frame with my elbows. At that instant the pilot regained control and started to pull out of the dive, forcing me down and farther out the hatch. The navigator, changing from pusher to puller, grasped my parachute harness, heaved upward, and hauled me back aboard.

The aircraft damage seemed to be mostly superficial. Then we checked the rest of the world and found we were completely alone: no airplanes, no smoke, no war. We'd lost the rest of the 40-plane formation.

Getting back to base posed something of a problem. We had no idea of our exact location—the ground was obscured by clouds. But the navigator had an ingenious solution. Our maps had color overlays indicating heavy flak areas. He drew a course from Vienna to Graz and gave the pilot a general heading to follow. Minutes later familiar bursts appeared ahead: Graz flak. We turned toward Maribor, then to Zagreb, letting the enemy gunners of each unseen city unwittingly direct us to the Adriatic coast and Radio Foggia, the homing station that played Benny Goodman's "Flying Home" for crews to vector on.

As we neared the coast I changed radio channels to try to pick up chatter from the lost B-24s. Through the directions,

NASM

requests, and landing instructions from emergency bases on the north Italian coast and the tiny island of Vis, I heard:

"Bubbly Tower, Dog Easy, five miles north of the field, two engines out, wounded aboard, no landing gear. We've got to come in on our belly."

"Dog Easy, cleared for immediate straight-in approach and landing. Wind is from southwest at about 10. Don't bother to call anymore. Good luck."

"Bubbly Tower to crash crews, belly landing on Runway Two. Get moving." There was a pause, then static, and then: "Oh, God. Bubbly Tower to crash crews. Abort. You can't do anything now."

No one said a word. Over the top of the oxygen masks our eyes darted nervously, stared in disbelief, or blinked with anxiety. We just looked at one another, then looked away. Our euphoria at having survived the flak barrages turned to a strange guilt for having done so.

Eventually we touched down at Manduria and taxied to a stop. In our squadron area sat only one other B-24, the *Illegal Eagle*. A mechanic appeared in a jeep. "Where's the rest of the 722nd Squadron?" we asked.

"You're it," he said. "Only got two back."

Debriefing went by in a stupor. In the barracks, officers were already cataloging the possessions of the missing. We were to learn that the lead aircraft had been hit by one of the first barrages and lost all communications. Other airplanes were hit, but many that we thought were lost had staggered into relief fields. One crew crash-landed in northern Italy and another bailed out over the Adriatic and was picked up by air-sea rescue personnel. Two weeks later a crew we'd given up for dead would return wearing dirndls and peasant blouses. They'd parachuted over Yugoslavia and walked through enemy territory with a band of Marshal Tito's Partisans.

But we didn't know all that on the night of October 7. We only knew we had to fly 45 more missions. I glanced around at the sad and withdrawn men in the barracks, some lying on their bunks staring at the ceiling, some writing letters or silently busying themselves with aimless little tasks. Some of us were facing the realization that we might not make it. And some of us were praying for a serious but not life-threatening wound that would ground us—an explosion that would render us too deaf for flight status, loss of the tip of the little finger, a back injury that would prevent us from sitting or crouching. And there were rumors of faked breakdowns or an "accidental" discharge of a .45 service revolver into the foot.

But no one I knew went that far to avoid combat—we were fearful of what others would say. We flew not for the American flag but because we couldn't stand to be suspected of cowardice. Many heroes have died for their countries simply because they were afraid of looking bad. That's why crews plowed through fighters and flak when they could have claimed a rough-running engine and turned back, and I suspect that's why infantrymen went on seemingly hopeless reconnaissance patrols and submariners pursued the enemy through mined waters. It was that unspoken fear that banded us together in 1944. All we had was each other.

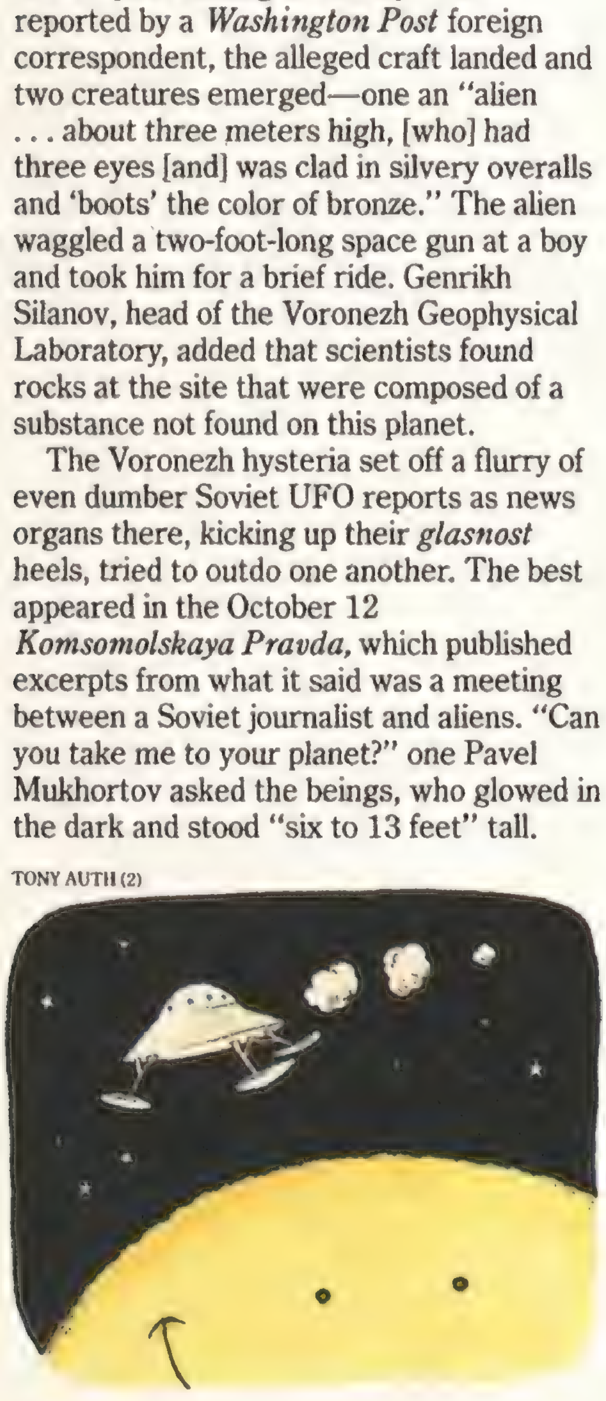
—Jack Keil

It Came From the U.S.S.R.

Possibly you've forgotten the fine points of the UFO incident that rocked the Soviet city of Voronezh last fall, so to review: On October 9 the Soviet news agency Tass reported that an unspecified number of tall human-like creatures with "very small heads," accompanied by a midget robot, landed a "banana shaped object" in the city and terrorized local youths. This close encounter at the provincial city 300 miles southeast of Moscow allegedly began at 6:30 p.m. on September 27, when the teens, who were playing soccer in a park, saw a "pink shining in the sky." As reported by a *Washington Post* foreign correspondent, the alleged craft landed and two creatures emerged—one an "alien . . . about three meters high, [who] had three eyes [and] was clad in silvery overalls and 'boots' the color of bronze." The alien waggled a two-foot-long space gun at a boy and took him for a brief ride. Genrikh Silanov, head of the Voronezh Geophysical Laboratory, added that scientists found rocks at the site that were composed of a substance not found on this planet.

The Voronezh hysteria set off a flurry of even dumber Soviet UFO reports as news organs there, kicking up their *glasnost* heels, tried to outdo one another. The best appeared in the October 12 *Komsomolskaya Pravda,* which published excerpts from what it said was a meeting between a Soviet journalist and aliens. "Can you take me to your planet?" one Pavel Mukhortov asked the beings, who glowed in the dark and stood "six to 13 feet" tall.

TONY AUTH (2)



"There would be no return for you and it would be dangerous for us," came the reply. "You might bring thought bacteria."

The Voronezh story fizzled when it emerged that only the teens, not the "many witnesses" mentioned in some reports, had seen the anomalies. As for the mystery rocks, they turned out to be hematite, one of the most common sources of iron ore.

Over here, however, the story got long, gleeful play. "The Soviet press did not take off on this as much as our own media did," notes prominent UFO skeptic Paul Kurtz, chairman of the Committee for the Scientific Investigation of Claims of the Paranormal. One of the reasons given for our media's field day was that Tass, a famously boring wire service, had never before given serious attention to UFOlogy. But as the *New York Times* pointed out, last summer Tass wrote of a UFO that sprayed a Soviet hillside with "mysterious, tiny golden hairs." And in January 1985 Tass circulated a report about a "sharp-nosed wingless 'cloud-aircraft' " encountered by Aeroflot flight 8352.

No, I suspect our Voronezh media overkill is more likely a sign of our national appreciation of emerging Soviet mushmindedness. If this is the case, reporters here should have plenty to write about in the years ahead. Sure, the Soviets have a long way to go in closing the credulity gap on a nation that has thought-infected the world with Bigfoot, L. Ron Hubbard, and *Communion* author Whitley Strieber, but there is every reason to believe that the Soviets will become highly competitive players in a very short time.

U.S. officials closed the book on UFO studies in 1969 when the Air Force's Project Blue Book ended. But in the U.S.S.R. the government appears to be opening the book ever wider. This should have fascinating results, such as the unique groups that will arise from the coupling of Soviet fringe thinking and Soviet bureaucracy. Two examples give us an idea of what to expect. In the 1987 book *Above Top Secret,* a UFO treatise that blends documentation with breathless speculation about CIA conspiracies to hide the UFO truth from the public, author Timothy Good mentions the 1978 formation of a UFO research group under the direction of Vladimir Azhazha, a UFOlogist frequently quoted during the Voronezh episode. "The group was . . . under the auspices of the A.S. Popov Scientific and Technical Society for Radio, Electronics and Communications," Good writes, and hats off if he got all this right, "and called itself BPVTS, short for *Blizhniy Poisk Vnezemnykh Tsivilizatsy s Pomoshch'yu Sredstva Radioelektronika* (Search for Extraterrestrial Civilizations in the Neighbourhood of Earth by Means of Radio-electronics)."

The hot group in the '80s, Good writes, is the modestly titled Commission for the Investigation of Anomalous Atmospheric Phenomena, founded in 1984. The salient point is that the Soviet government is encouraging citizens' interest. Some UFO students think this will cause quite a stir in a populace that possesses what Kurtz calls "atrophied critical faculties." Adds NASA engineer and UFO skeptic James Oberg, "The Soviet public's current interest in flying saucers is in many ways the *fault of* the government." Oberg argues that many famed Soviet sightings—among them the 1980 report of a reddish crescent-shaped UFO—result from twilight launches of spy satellites and other military payloads. "Rather than explain the launches," he says, "the government simply let the rumors circulate and in some cases even encouraged the spread of rumors . . . . With that sort of fertilizer on the mind . . . it's no wonder the Soviets go absolutely berserk when a UFO story occurs."

Irresponsible, I know, but I'm still annoyed at them for sending us Yakov Smirnoff. So here's hoping Soviet thought bacteria have a long and manure-fed growth spurt.

—*Alex Heard*

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THE ZERO

ONE STEP BEYOND

An object lesson in the element of surprise.

by Steven L. Thompson

The fighter, perhaps more than any other warplane, exerts a powerful grip on the imagination. The reason may be quite simple: the fighter evokes two of our most primal fascinations—flying and fighting. Just as the shark embodies both beauty and terror, the fighter embodies many of humankind's most admirable aspirations as well as its most loathsome capacities.

A very few fighters exercise a hold on us that is particularly strong because of what they symbolize, and one of these is Japan's "Zero." This World War II carrier-based naval fighter is more than just another relic of the 20th century's most devastating war. The Zero is a cultural and technological signpost, and even today it is telling us things we're only now beginning to understand.

*The agile little Zero was a sight much feared by American pilots in the Pacific war. This rare survivor (right) flies for the Confederate Air Force. Some said Zero designer Jiro Horikoshi (below) copied foreign ideas; though he adapted some, his 12-*shi *rewrote the book.*

NATIONAL ARCHIVES

PHILIP MAKANNA/CAF

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For most Americans who remember Pearl Harbor, the new Japanese fighter was a winged shock that appeared, seemingly from nowhere, on December 7, 1941, in the skies over Hawaii and, hours later, over Clark Field in the Philippines. Piloted by skilled and aggressive warriors completely unlike those caricatured in the popular press of the day, it swept American airplanes and pilots from the skies with almost contemptuous ease. Where, U.S. airmen wondered as they surveyed the wreckage of their airfields and their assumptions, were the maladroit, bucktoothed, bespectacled pilots they'd believed were the mainstay of the Imperial Japanese air forces?

They weren't flying Zeros; they weren't flying *anything*, for

"Never attempt to dog fight the Zero," urged a U.S. Army report. Japan's new lightweight fighter could turn inside anything the United States put in the air. External tanks, like the ones carried by these Rabaul-based Zero 22s (below), gave it unprecedented range.

that matter. The caricatures were just that: a racist fiction with a technical topspin. When the Zeros and their pilots knocked down everything thrown up at them in the first months of the Pacific war, they also knocked down a century's accumulation of arrogance.

After Commodore Matthew Perry "opened up" Japan in 1853, he found a feudal society that had a long, hard road to travel before it could meet the industrialized West on its own terms. Along that road, leaders of Japan's technological infrastructure made some colossal blunders and produced many blatant copies of Western products, often very poorly. Yet the Western perception of a backward Japan was so persistent that when the copies became better than the originals—and when Japanese originals appeared—few took notice.

The Zero was one original that *everyone* noticed, but not at first and not in time. In October 1937 there was simply an Imperial Japanese Navy document entitled "Planning Requirements for the Prototype 12 Carrier-Based Fighter." In that document the navy set out to compel its contractors to build the most advanced fighter in the world. The 12-*shi* (*shi* for *shisaku*, or "trial manufacturer," and "12" for the 12th year of Showa, the reign of Emperor Hirohito) was to be a carrier fighter that would combine unheard-of speed, agility, armament, and range. No airplane in existence could meet the navy's specifications.

When he first set eyes on the planning requirements document, Jiro Horikoshi was 34 years old. A graduate of the University of Tokyo's fledgling aeronautical engineering department, he'd been working for Mitsubishi Heavy Industries as an airframe designer for a decade and had already designed two airplanes, the 7-*shi* and 9-*shi*. The former was a commercial failure, but the latter became the Type 96 fighter, which Japanese Navy pilots used to seize control of the airspace over China during the second Sino-Japanese war. (The Type 96 was so numbered because it was accepted into active service in the 2596th year of the Japanese calendar. However, it was also designated the "A5M1" by the Japanese, who arrived at the

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designation this way: "A" was the code for carrier-based fighter, "5" for the fifth accepted into service, "M" for the manufacturer, Mitsubishi, and "1" for the first version. This system of nomenclature, coupled with yet another system describing "types," was confusing to outsiders, especially Americans, who devised an alternate system used during the war, much as NATO now uses its own names for Warsaw Pact aircraft. The Type 96 was called the "Claude" in the West.)

Horikoshi's story mirrors the rapid maturation of Japanese aviation. Weaned on tales in boys' magazines of derring-do over France during World War I, he dreamed of flying over the fields of his home in the Gunma prefecture, piloting an airplane of his own design. After he had been with Mitsubishi only a few years, the Japanese Navy decided to free itself from reliance on foreign hardware, a decision embodied in its policy statement "Project Aviation Technology Independence." Thus were created the conditions that would allow Horikoshi to show the world what a Japanese engineer could do.

While he was a young newcomer to Mitsubishi, Horikoshi had been sent on a postgraduate tour of the world's best aircraft manufacturers. He visited England, France, Germany, and the United States, and despite the view prevailing in those countries that Japan was still a primitive nation of imitators, Horikoshi decided that "... it would not take Japan very long to catch up with their small-airplane technology if we had proper government priorities and policy."

Driven by a vision of air power as the key to victory—a vision reinforced by early experience in China, where unescorted Japanese bombers had been shot down in droves—the Japanese Navy gave its domestic contractors precisely those "proper" priorities. It set higher performance goals for each new airplane, pushing still-uncertain Japanese designers past the limits of their educations (which had been provided largely by foreign instructors). By the time the requirements for a new fighter were dropped on Horikoshi's desk in late 1937 (see "Recipe for a Legend," below), he and his colleagues were ready for the challenge of the Zero.

But one segment of the Japanese aviation industry was not ready: engine technology in Japan still lagged behind that of Western powers. Japan's paucity of natural resources made itself felt in this area, because modern engines made use of advanced metal alloys Japanese engineers could only dream of.

Recipe for a Legend

"I could not believe my eyes," wrote Jiro Horikoshi, recalling his first reaction to the Imperial Japanese Navy's requirements for the fighter that would eventually become the Zero. "They were far more demanding than I had expected and seemed impossible to meet." In 1937, no engineer on earth would have disagreed.

The Japanese Navy asked for a maximum speed of more than 500 kilometers per hour (over 310 mph) at an altitude of 4,000 meters (over 13,000 feet). It specified that the fighter climb to 3,000 meters (9,800 feet) in under three and a half minutes and mount a pair of heavy 20-mm cannon in addition to two machine guns. It had to have an endurance of 1.2 to 1.5 hours on internal fuel only and at full power, and it had to be able to operate from a carrier deck—all this, and Horikoshi was expected to deliver it with an engine in the 1,000-horsepower class.

"Just glancing at the requirements made me gloomy," Horikoshi later wrote. Perhaps, but in less than two years he surpassed them with the Zero. And in some ways the Zero itself has never been surpassed. "As proof of this," the designer noted with understandable pride many years after the war, "there has never existed anywhere in the world a fighter powered by a 1,000-hp air-cooled engine that was faster than the Zero, even without comparable range and dogfight characteristics."

In December 1942, the U.S. Army Air Forces came to more or less the same conclusion, issuing a report comparing flight characteristics of the Zero with those of the P-38, P-39, P-40, P-51, F4F, and F4U—the best fighters the United States could field. The Zero's low wing loading—weight per unit of wing area—gave it the uncontestable lead in maneuverability. The lightweight fighter could turn inside its opponents, and its large ailerons produced rapid rolls. A Zero could pull up into a zoom climb and leave almost anybody behind.

But the Zero's advantage began to dwindle at speeds above 300 mph, and its float-type carburetor wouldn't allow negative-G maneuvers without loss of engine power—in effect, it couldn't push over into a descent. The large ailerons became a disadvantage when they stiffened in the grip of high-speed airflow (above 300 mph, the report noted, "it is virtually impossible to reverse a turn").

As a result, P-38s began engaging in high-speed diving attacks against the Zero, and pilots were urged to use turn reversal to escape a Zero on their tail. The Zero outclimbed the P-51 at low altitudes, but the U.S. fighter could outdive it. F4F pilots were advised to stick together and fight as groups. The

F4U could best the little fighter, which had half its horsepower, only if it kept up its speed and altitude or used a pushover dive to escape. It would take the Grumman F6F Hellcat, with its low wing loading and a 2,000-horsepower engine, to finally end the Zero's ascendancy.

The Other Zero

On Christmas Day, 1941, a squadron of American mercenaries employed by China, stationed in Burma, and flying the venerable Curtiss P-40 became the first Western airmen to turn back the Japanese, claiming several "Zero types" in the process. In that day's victory was born the legend of the Flying Tigers, the mavericks who beat the immeasurably superior Mitsubishi Zero. But the Zero was a navy fighter. As Japanese records show, it never fought over Burma.

A few years earlier, the Nakajima company had built a fighter weighing 5,000 pounds—one-third less than a P-40 but nearly as fast and with many times the combat range. Still, it seemed sluggish in high-G maneuvers, and the Japanese army turned it down. But its engine went into production for the navy's Zero, which was about the same size and shape.

Japan had two air forces, and both were as wary of each other as they were of foreign adversaries. Army ammunition did not fit navy machine guns, and its radios could not broadcast on navy frequencies. In the spring of 1941, it fell to the army to prepare for an attack on British Malaya from what is now Cambodia—too long a trip for the older army fighters. So the rejected Nakajima prototype was modified to increase its maneuverability, and the army took it into service as its Type One fighter, the Hayabusa, or "Falcon." Initially just 50 of these went to war; slower Type 97 fighters with fixed landing gear and two rifle-caliber machine guns made up the rest of the fleet.

Over Malaya, the Hayabusa proved as redoubtable as the Zero: not one was shot down. But over Burma the heavier bombers suffered terrible losses when the Type 97 fighters could not keep up with them. Twenty-five Hayabusas were therefore ordered in to escort a raid on December 25.

The Flying Tigers were waiting, and the resulting battle revealed the weaknesses in Nakajima's weight-saving construction.

In July 1942 the Tigers were replaced with U.S. Army pilots, who likewise believed they were fighting—and often beating—the Zero. By the end of the year, however, enough wrecks were found to reveal conclusively that Japan had deployed an entirely different fighter on the Asian mainland. It bore a close enough resemblance to the Zero that it was easily mistaken for one. The Americans dubbed it "Oscar."

The Hayabusa was phased out in 1944, by which time 5,000 had been built, making it second in number only to the Zero.

—*Daniel Ford*

Horikoshi had already encountered that painful reality while designing the Type 96 fighter; because he was forced to use a less powerful engine, he had to find other means of producing high performance. His solutions—all-metal semi-monocoque construction with internal wing bracing and flush riveting—allowed the 96 to outperform its rivals even though its engine produced less than half their power.

The powerplant situation had not improved by the time the requirements were set for the 12-*shi*, so Horikoshi faced a seemingly impossible engineering task. First he tried, as any reasonable engineer would, to get the priorities realigned to make meeting them more reasonable. But the navy stuck to its demands. Horikoshi was expected to meet the requirements with an engine of far less than the 1,200 horsepower installed in the F4F Wildcat, which the Zero would soon meet.

Horikoshi's health declined rapidly as he sought a solution to the paradox. A fighter's worth, perhaps more than any other airplane's, is dependent upon its engine. Forced to use an engine with sub-par performance, Horikoshi had to reexamine every aspect of airplane design and construction, and in the process he made several important breakthroughs in aerodynamics, stress analysis, and flight controls that were appreciated in the West only after the war.

The first breakthrough involved the skeleton of the airplane. With the limitations imposed by the engine, the only way Horikoshi could make his fighter fly higher, climb faster, maneuver more nimbly, and go farther than its adversaries was to make the airplane's structure lighter. But early in the sketching phase he decided, based on conventional stress analysis, that he could never reach his weight goal. At this impasse, he went back and reviewed the standard stress tables. It was a wise decision, for ultimately he concluded that the

A Zero pieced together from wreckage in China yielded valuable intelligence to the West.

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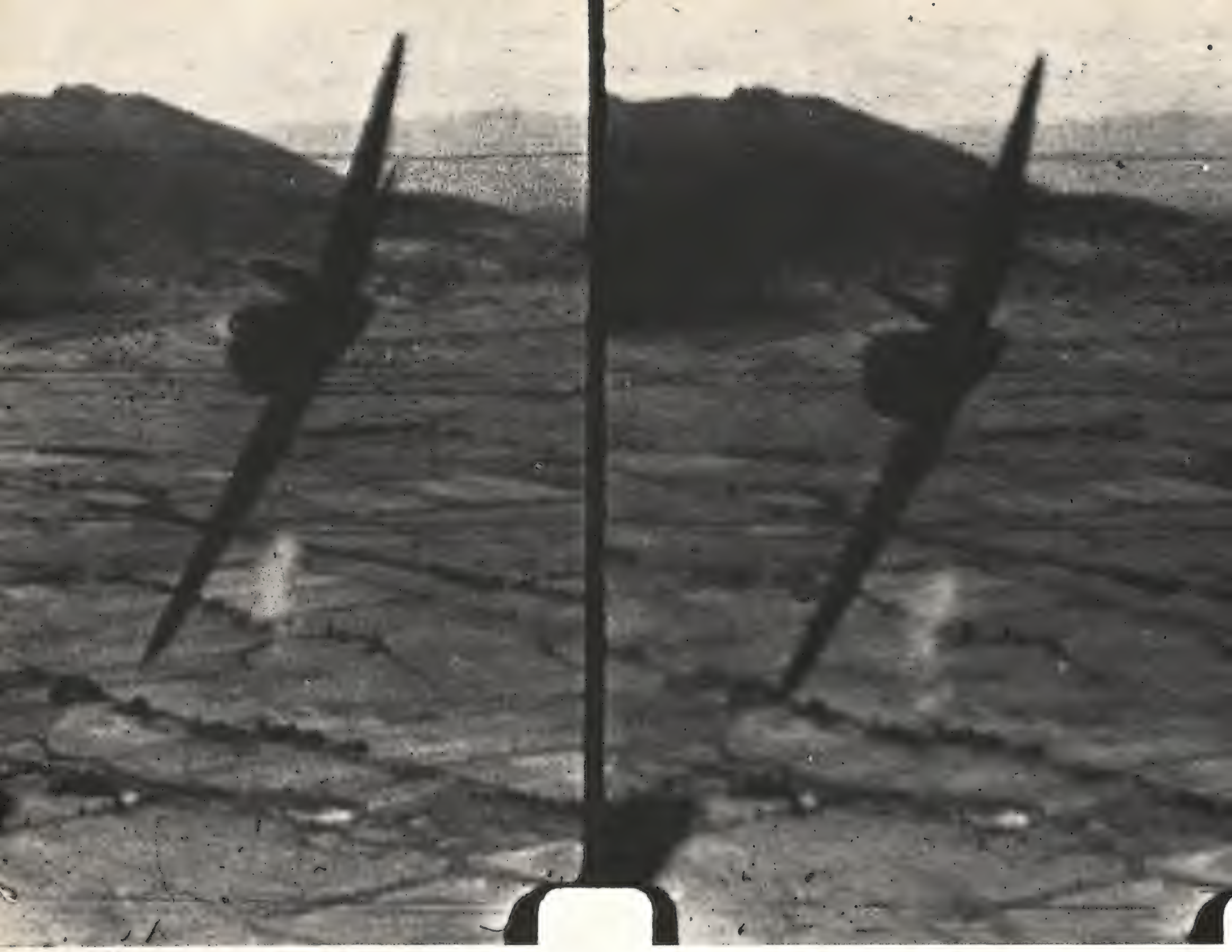

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figures being used worldwide were far too conservative and, perhaps more important, too uniformly applied. Not all structures in the airplane needed to be built to the same stress specifications, he thought. Some could be completely redesigned and made thinner and lighter.

Aeronautics, as both a science and an engineering discipline, was not even four decades old, and Horikoshi's bold approach paid dividends. His countrymen were making similar strides in metallurgy—another development ignored or misconstrued in the West. A fellow engineer told Horikoshi of a new kind of aluminum alloy being made at Sumitomo Metals, one that promised a far higher strength-to-weight property than that of a then-current standard alloy called duralumin. Sumitomo called its new material "Extra Super Duralumin." It was just what the doctor ordered for the 12-*shi*.

Because of his fanatical work on saving weight, and because the Japanese Navy did not ask for bulletproofing of the cockpit or the use of heavy self-sealing fuel tanks, the figures added up, in the end, to the elegant prototype that was hauled on carts from the Mitsubishi plant to a nearby airfield for its first flight test on April 1, 1939. At twilight the prototype took off and flew flawlessly.

On July 31, 1940, after 119 test flights and the crash of the second prototype, the fighter was accepted into service. It was given the official name "A6M2 Type 00 Deck-Landing Fighter" because it followed the A5M1 Type 96 into the Japanese Navy. But because its calendar designation was "00" for the Japanese year 2600 (the airplane was never called the Japanese equivalent for "Zero-Zero," though the double-zero was used in its early appearances in Western reports, shortened very soon to the single digit that matched its name), it immediately became "*Rei-sen*" to its pilots and ground crew—*rei* for "zero" and *sen* for *sentoki*, or "fighter." On September 13, over Chungking, China, it eliminated 27 Chinese and Soviet fighters. That day, not a single Zero was lost.

Over the next year, the Zero ran roughshod over all its opposition. Had it been engaged in the European air war then raging between the British and Germans, the Zero and its exploits would have been front-page news. But it was fighting in China, in what was, to Westerners, a largely forgotten and invisible war. The new fighter's exploits—and its significance—went mostly unrecognized.

The popular press in the United States continued to portray Japanese aviation as almost contemptible. A story on Japanese air power in the September 1941 issue of *Aviation* included such appraisals as: "American aviation circles don't have to take a second look at the leading military aircraft types to decide that most of them are obsolete or obsolescent." A little over two months later, those "obsolete" aircraft were wiping out U.S. air power in the Pacific. The British and Dutch like-

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The Zero (at left, a 21 in its final moments) had its vulnerabilities. An A6M2 data plate (above) indicates an equipped weight of 2,365.3 kilograms—about 5,215 pounds. The U.S. Navy's F4F-4 Wildcat tipped the scales at 7,975 pounds, but the F4F had armor.

wise went down before the Zeros within months of Pearl Harbor. Less than a year after the Pacific war began, the U.S. Army Air Forces Intelligence Service issued its summary of the fighting and flying characteristics of the Zero, compiled in a fly-off between a captured Zero and the leading American fighters. The first recommendation made to U.S. combat pilots tells the story best: "Never attempt to dog fight the Zero."

By late 1942 Allied pilots who had confronted the Zeros already knew how foolish it was to employ conventional fighter tactics in Zero-fighting. And by then the legend of the Zero was firmly established, in both the United States and Japan. Americans who knew how potent the fighter was insisted that it had to have been copied from a U.S. design. For their part, many Japanese mistook the startlingly easy initial victories of the Zero for a lasting performance advantage and came to believe the airplane was virtually invincible. That faith would ultimately hinder development of newer and better fighters, with fatal consequences to the Japanese cause.

One of the most nagging questions about the Zero among Western leaders was why it had been such a surprise. Until very recently, aviation lore on both sides of the Pacific held that the racial prejudice of senior commanders, coupled with the sheer incompetence of Western intelligence agencies, produced the ignorance that almost lost the West the Pacific war. This belief was strengthened with the publication of General Claire Chennault's memoirs, *Way of a Fighter,* in 1949.

In 1937 Chennault had been recruited by the Kuomintang, or Chinese Nationalists, under Generalissimo Chiang Kai-shek to bolster the failing Chinese air forces. Chennault had retired from the U.S. Army Air Corps with a reputation as a maverick because of his then-unconventional beliefs about air combat. The Chinese, less concerned about his unusual thinking than were his colleagues, enthusiastically paid him to help their cause, which he did with immediate effect. Less effective, he claimed in his memoirs, were his attempts to alert Washington to a new generation of Japanese fighters. The United States was blindsided at Pearl Harbor, he implied, because of bureaucratic inertia, ignorance, and jealousy in Washington.

It was not until the publication of a landmark piece of detective work in the winter 1987 issue of *The Aerospace Historian* that a balanced explanation was offered as to why the West was unprepared for the Zero. In "Assessing the Japanese Threat: Air Intelligence Prior to Pearl Harbor," William M. Leary of the University of Georgia shows that, as with much popular history, the story of the Zero was warped by fallacies, half-truths, and outright errors.

Leary's painstaking sifting of the historical record reveals that Western intelligence services did gather and disseminate raw data on the Zero. Chennault's reports, as well as those of other knowledgeable observers, were not ignored at the highest levels. The man who was to head the wartime U.S. air forces, General H.H. "Hap" Arnold, briefed the Army War College in October 1937 on the rising threat from Japan, saying, "There is abroad in the world a first-rate air power that knows how to use its strength." Furthermore, Leary points out that Army chief of staff General George C. Marshall "warned officials at a high-level conference that a fast new Japanese pursuit [fighter] had grounded the Chinese Air

Force" a day after meeting with Chennault in late 1940.

More telling, in light of what was to happen later, is Marshall's February 1941 correspondence with both Lieutenant General Walter C. Short, commanding general of the Hawaiian department, and Major General George Grunert, commander of the Philippine department. In his letters, Marshall noted the capabilities of the Zero and warned that the comparable U.S. fighters were clearly deficient. Finally, in refutation of Chennault's postwar claim that the Army "devoted a blank page to the Zero" in its early manuals, Leary shows that eight months

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before the attack on Pearl Harbor, the Army issued a revised edition of *Field Manual 30-38* containing reasonably accurate data—though no pictures—describing the Zero.

So the West *was* warned. Intelligence services did their jobs. But in the end it was the *users* of the intelligence who failed to appreciate the significance of the Zero. In the Army Air Corps, ignorance about and disdain for Japanese pilots and airplanes was nearly universal, as evidenced by the recollections of Herbert H. Ellis, a pilot from the Third Pursuit Squadron based in the Philippines in December 1941 who told Leary, "I knew almost nothing about Japanese aviation before the war and neither did any of my contemporaries." Ellis added that he and his fellow pilots believed "all Japanese products, including aircraft, were imitations of inferior quality . . . . It was a stock joke (half believed) that Japanese pilots had defective vision."

The intelligence on the Zero was ridiculed less by the U.S. Navy, but not much less. A few pilots took the threat seriously, and one of these was Lieutenant Commander John S. Thach of VF-3, a carrier-based fighter squadron equipped in the summer of 1941 with Grumman F4F-3 Wildcats. Unlike most of his colleagues, Thach thought he detected truth in the reports he read because they seemed to have been written by a fighter pilot. Two months before Pearl Harbor, he worked out the tactic that would prove to be vital to ending the domination of the Zero. The Thach Weave, developed using kitchen matches on a tabletop in San Diego, was inspired by Thach's respect for his adversaries' potential. Flying the Weave, pilots of a pair of Wildcats would simply turn toward each other if they were jumped by Zeros and thereby allow each pilot a shot at the opposing partner's pursuer. The pair of airplanes continued these turning maneuvers until their paths constituted an intertwined series of S-turns—a weave.

Six months after Pearl Harbor, Thach's theories got their trial by fire. At Midway the American and Japanese naval air fleets clashed in full force. The result was a victory for the United States, as well as what has come to be regarded as the turning point in the war. Thach's Weave had worked. The individually inferior Wildcats defeated the Zeros with his tactics and helped make possible the sinking of the Japanese carriers, which marked the beginning of the end of Japan's long winning streak. Thach later said that " . . . without that intelligence report that was said to have come out of China, I think we would have gone along, fat, dumb, and happy, and not had nearly the success we did have."

Thach and his thousands of American compatriots went on to rack up successes against the Zero and every other airplane Japan fielded. Horikoshi himself noted that when technology is being pushed to its limits by battle, the maximum lifespan of any fighter is at best only two years. Yet the Zero, truly obsolete by 1943, was forced to bear the brunt of the air war until the very end, the victim of its own early success.

In his memoir, *Eagles of Mitsubishi,* Horikoshi tries to explain some of the lessons of the Zero. "Unlike the imaginative work of an artist," he writes, "the task of an engineer is always shadowed by severe, realistic conditions and requirements. But in order to achieve a high quality of creativity within this framework, the engineer must use free imagination to crack through ordinary paths of thinking, and this must be coupled with complete rationality . . . . During the design of the Zero and other airplanes, I was deeply engrossed in the problem at

The USS Missouri *survived this suicide attack. Zero designer Horikoshi was appalled by the kamikazes.*

hand, but I had to constantly keep in mind that it was necessary to go one step beyond the normal limits of thinking within the given conditions. I think the Zero is a good symbolic example of what can be achieved by thinking 'one step beyond.' "

Horikoshi's book was published in 1970, a time when few in the aeronautics world would have disputed his conclusion. But the lesson imparted by the Zero had registered only incompletely in the West, as shown by the U.S. automotive establishment's reaction to the growing numbers of Japanese cars then being sold in the United States. When the numbers began to look significant even to U.S. industry leaders, the cars and their designers were derided as casually and arrogantly as Horikoshi and his airplanes had been. The conventional wisdom in Detroit in the early '70s was that the Japanese cars were selling simply because they were cheaper.

It was not until 1974, when Soichiro Honda's engineers met the challenge of the Environmental Protection Agency's new exhaust emission rules without the use of a catalytic converter—a challenge most American manufacturers claimed could not be met, at least not economically—that a few in Detroit began to understand they were in the midst of their own Pearl Harbor and that the new Zeros were called Honda Civics. Honda had gone "one step beyond" and established victories in the marketplace that led, by the time of Jiro Horikoshi's death in 1984, to significant changes in the economies and cultures of both Japan and the United States.

Viewed not as a weapon of war but as an industrial artifact, the Zero can be understood as a harbinger of a sea change in industrial culture. Even the way it was built is now instructive. The same *Aviation* story that dismissed Japanese air forces as obsolete deprecated Japanese methods of industrial production: "Aero industries in Japan, in sharp contrast with the methods elsewhere, make extensive use of small shops and factories, each employing a small number of workers." According to the dogma of the day, which praised single-factory manufacturing, such a system was considered backward. Not so today.

The *Wall Street Journal*, in a story last March on how Los Angeles has become one of the major U.S. centers of industrial production, noted that the area's prosperity is based on small, specialty subcontractor shops. Not coincidentally, similar shops supply the all-conquering Japanese automobile industry, and in Detroit the system (now called "modular manufacturing") is being taken very seriously as one of the means of economic survival in the car wars. In Japan a half-century ago, it was the way Mitsubishi produced more than 10,000 Zeros under conditions of incredible disruption and hardship. Designed to destroy, all but a handful of those Zeros have themselves been destroyed. But their legacy, clearly, lives on.

A U.S. carrier ships home a load of captured Zeros. The fighter was studied even after the war to learn its secrets.

NATIONAL ARCHIVES

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Ticket to Ride and Ride and Ride...

A frequent flier's fantasy comes true with a 30-day Pan Am WorldPass.

Story and photographs by Mark S. Wexler

The author catches the shade of a 747 on final approach to Princess Juliana International Airport at St. Maartens in the Netherlands Antilles (left).

White House sidewalk, Washington, D.C.

It was 4:30 a.m. and the cab swerved to avoid another cow crossing the road. Fires burned in trash cans, illuminating families huddled in the night. As the cab stalled again, I lost all hope that my driver would reach the Delhi station in time for my train to Agra and the Taj Mahal. But no matter—by this time the next day I'd be back at 30,000 feet, sipping Perrier en route to Moscow.

In my pocket was the Rolls-Royce of frequent flier programs: Pan Am's WorldPass 30. Achieved after logging 175,000 air miles, it entitles the bearer to 30 days of free first-class air travel nearly anywhere the airline flies. Kenya safaris, the Eiffel Tower, the string bikinis of Rio—I was determined to make the most of it.

Some find airline travel torturous, but for me it has always been a magic carpet. While other kids were swapping baseball cards in grammar school, I studied airline schedules. When I became a photojournalist, I spent nearly as much time aloft as on the ground. I accumulated mileage at an astounding rate, and the more I got the more I wanted. Soon I was making stopovers that weren't even close to my destination just to gain a hundred more miles. As a fellow passenger once observed, "A professional frequent flier can't be stymied by only going places he wants to be."

Palace guard, London (opposite, right)

Paris (right)

Masai Mara Game Reserve, Kenya

Dancers at Frankfurt-Main International Airport, West Germany

"Welcome to our new international airport," said the Soviet teenager, gesturing across Red Square with a grin. He was, of course, referring to the West German pilot who landed his Finnish Cessna near there in May 1987. I'd been photographing the changing of the guard at the Kremlin when Vladimir introduced himself and immediately got down to business. "How much for the Nikes?" he asked in flawless English. After I explained they were my only pair, Vladimir asked for Marlboros. I'd been warned about this, but aboard the 727 into Moscow all the Marlboro cigarettes had sold out. "People know that a pack can get them food, shelter, or through a line at the airport," a flight attendant had said.

The 10-degree temperature brought the photo shoot to a close and I retreated to the Intourist Hotel, one of my dozen overnight stops. I set the alarm for 5 a.m.—the flight to Istanbul was an early one—and downed my weekly malaria pills in preparation for next week's African safari.

All roads lead to Frankfurt. One quarter of all my flights landed there, but I never once got out of the airport. To fly from Istanbul to Budapest or from Nairobi to Athens, a Pan Am ticket holder must pass through the airline's Frankfurt hub. So many flights from all over the world connect here that the airport has developed into a city unto

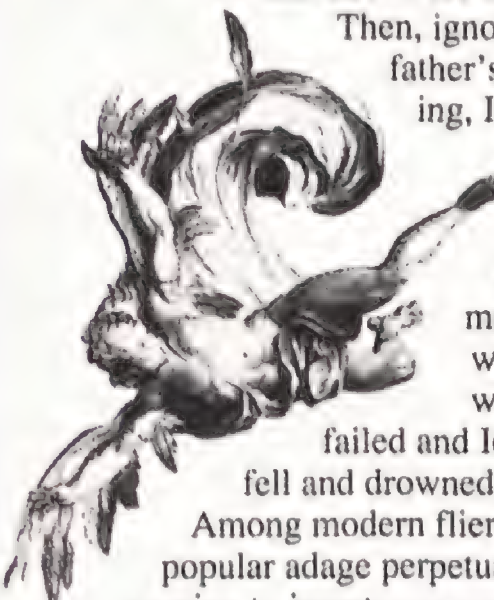
The Parthenon, Athens


VISION

Man's Early Dreams of Flight

In Greek myth, Daedalus makes wings of feathers, wax, and linen and flies from the island of Crete across the Aegean Sea.

China, India, Persia, Norway, Egypt — even the American Indians wrote or drew folklore of humans who could fly. Best known are Daedalus, a noted Greek architect and inventor, and his son Icarus, who were being held captive on Crete. The father crafted wings, and the pair flew safely for many miles a few hundred feet above the sea. Then, ignoring his father's warning, Icarus flew higher. The sun melted the wax, his wings failed and Icarus fell and drowned.



Among modern fliers, a popular adage perpetuates this warning to impetuous youth: "There are old pilots, and there are bold pilots," the saying goes, "but there are no old, bold pilots."

November 21, 1783: First Free Flight of a Manned Balloon

Pilatre de Rozier and Marquis d'Arlandes fly five miles across Paris in 25 minutes.

The hot air balloon was invented by Joseph and Etienne Montgolfier, who investigated why smoke rose from a fire. Their first public test, a sphere of paper-lined linen, rose 6,000 feet! Their next successful balloon carried passengers — a sheep, a duck, and a rooster. Initially, France's Louis XVI insisted the first human flight be performed by two condemned criminals, who had little to lose. But scientist de Rozier and the nobleman

1891 - 1896: First Successful Series of Manned Glider Tests

Otto Lilienthal makes 2,500 flights to become known as "The Father of the glider."

Centuries earlier, tethered gliders and kites were flown by the Chinese and Japanese; in wars, enormous manned kites were used for fire-bombing and spying.

But Lilienthal's glider research had no equal. A German, he studied storks and other gliding birds for 25 years, then wrote a respected book on aerodynamics. When he turned to building gliders, he used willow rods and cotton cloth; some said his craft looked like huge white bats. Lilienthal flew them grasping the framework with his arms, swinging his legs and trunk to steer. (Modern hang gliders use much the same technique.) He launched himself from hills and once flew 1,150 feet. He was working on an engine for powered flight, but in 1896 on a routine test, a gust of wind stalled his glider and he fell 50 feet. His back broken, Lilienthal characteristically wrote a crash report. He died the next day.

December 17, 1903: First Powered Manned Flights

Taking turns, Orville Wright goes first, piloting the plane 120 feet in 12 seconds. On the fourth and final run, brother Wilbur flies for 59 seconds and covers 852 feet.

April - September, 1924: First Flight Around the World

Eight U.S. Army airmen take a 175-day, 72-stop voyage.

During the two decades after the Wright Brothers' flight, pilots everywhere yearned to go higher, farther, faster — and first. By 1924, airplanes had gone to war, carried mail and passengers, crossed the American continent, refueled in flight, landed on boats and stunted upside down and under bridges; one irresistible challenge that remained was a flight around the world. The U.S. Army provided crews and four two-seat, open-cockpit, single-engine Douglas World Cruisers. Starting in Seattle and flying west, the team lost one plane against a mountain in Alaska, and another was ditched in the Atlantic after an oil pump failure. (Both crews were rescued.) After five and a half months, including some lengthy

stops for repairs, the two surviving craft returned to Seattle, each having logged more than 360 flying hours. In 1986, the lightweight *Voyager* airplane went around the world in 216 hours — *nonstop*. In 1988, making two quick stops to refuel, a Boeing 747-SP made the trip in slightly less than 37 hours.

May 20 - 21, 1927: First Nonstop From New York to Paris

Charles Lindbergh, flying alone, makes the trip in 33-1/2 hours.

The $25,000 prize for this aviation "first" was offered in 1919, but no one dared risk it; airplanes couldn't fly that far. Finally, a new engine was

1940 - 1945: First and Largest Buildup of Military Airpower

American, British, and Russian plants build 500,000 airplanes.

Many say that World War II was the only war to be decided by airpower. More than others, it was won by civilians who stayed at home and built airplanes. When the U.S.

entered the war, the military had fewer than 9,000 aircraft. It needed all kinds: bombers, transports, fighters, and scouts, and during the next four years Americans built 300,000 airplanes, 96,000 alone in 1944. (Russian and British allies also turned out several thousand planes a month.) With many of its men at war, America's women went to work in the factories. "Rosie the Riveter" not only made planes, tanks, and ships, she changed the country's work-force, staying on the job in unprecedented numbers. One mainstay of the war was the Boeing B-17 "Flying Fortress." At its peak in March 1944, the Seattle plant built an average of 82 of the four-engine bombers a *week*. To camouflage its work, a fake town was built on the plant roof, complete with cars and roads, houses, trees — and a real cow.

October 14, 1947: Man's First Flight Past the "Sound Barrier"

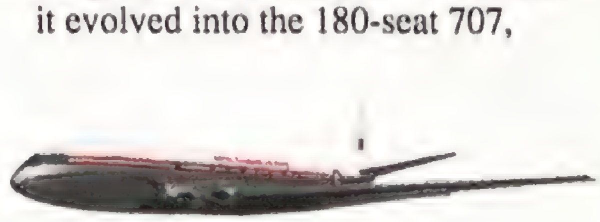
Capt. Charles Yeager pushes the rocket-engined X-1 to Mach 1.06.

During the war, pilots in new powerful fighters learned that high-speed dives often created severe control and vibration problems; nearing 600 mph, some planes shook apart. A "sound barrier" had always

May 2, 1952: First Commercial Flight of a Passenger Jet

On its initial trip from London to Johannesburg, the British Comet *cuts flying time in half.*

Early postwar passenger airplanes were virtually all propeller-driven and American-built. But British de Havilland gambled on a pure jet, with two engines encased in each wing. The Comet was small — 36 seats. But it was cheap to fly (jet fuel cost less than high-octane gas) and easy to maintain (fewer engine parts). More importantly, it was *fast* — 500 mph, nearly twice the speed of prop planes. Airlines rushed to buy Comets, but a string of crashes — three in a 12-month period, and two more blamed on metal fatigue — grounded the Comet in 1954, ruining its commercial success. That same year, drawing on its swept-wing B-47 and B-52 jet bombers, Boeing flew a four-engine prototype of the first American passenger jet. Known as the "Dash 80," it evolved into the 180-seat 707,



which was itself followed by U.S. planes made by Douglas and Convair. Today, over 10,000 jet transports have been built in the western world — more than half of them by Boeing. Since 1952, the Comet and its successors have changed the way the world's people think about travel — indeed, the way they think about the planet.

April 12, 1961: The First Human to Fly in Space

Soviet cosmonaut Yuri Gagarin orbits once around the earth.

In 1957, the Soviets launched Sputnik, the earth's first artificial satellite, and the "space race" was on. Four years later, at 27, Gagarin rode a

July 20, 1969: First Men to Walk Anywhere Other Than on Earth

Apollo 11 Neil Armstrong and Buzz Aldrin land on the moon.

Unlike most aviation firsts, this one was seen on live TV — most Americans spent that weekend watching it. Armstrong was first to climb down from the Lunar Module ("That's one small step for a man...") and Aldrin followed. Armstrong took pictures. Together, the two earthmen set up experiments, erected an American flag and gathered samples of rock and soil — 48 pounds (earth weight). Their moonwalk was less than three hours, all within 200 feet of the Module. They left mementos to honor U.S. and Soviet spacemen killed in accidents, messages of goodwill from 73 nations, and a plaque reading "We came in peace for all Mankind." Then they rendezvoused with the orbiting mother ship (piloted by Michael Collins) and flew home, where they were promptly quarantined for three weeks. (No moon germs were found.) None of the three flew in space again, but five more Apollo flights reached the moon. (The Apollo 13 flight was aborted when an oxygen tank blew up halfway to the moon; the crewmen returned to earth safely.) Moonwalks grew to more than a mile, and on the last three missions a "moon buggy" was employed to carry men and equipment on trips of several miles. Altogether, 12 Americans set foot on the moon between 1969 and 1972; the only humans ever to do so.

Of all the hopes and dreams in man's imagination, none have been so compelling or durable as his desire to fly. Through ancient myth and legend, literature and art is rich with tales of gods and men who gained the power of flight. Some scholars believe this wish evolved from primitive man's envy of birds and insects — their ability to rise above peril. A few think man's obsession with flight is rooted in subconscious memory — that we once knew how to fly but lost the skill, and only the yearning remains.

For whatever motive, men have been *trying* to fly for centuries. Many were killed in the process, and others were discouraged by serious injury. (Women apparently had better sense, since early records show few attempts.) Starting in the 12th Century, "tower jumpers"— perhaps convinced that their religion would protect them — climbed to the tops of castles or cathedrals and hurled themselves over the edge. Some fashioned wings, others did not. The result was much the same, governed by the laws of gravity (rate of increase of acceleration: 32.17 feet per second per second). The phenomenon continued past the 17th Century, and one jumper, a village deliveryman in Essex, England, offered this perspective: "I'm really a good flier," he said, dusting himself off after an unsuccessful two-story plunge, "but I cannot alight very well."

Leonardo da Vinci studied flight in the 15th Century and made remarkably modern drawings (Leonardo da Vinci's fifteenth-century sketch of a helix, is shown on this page). But the science of aerodynamics and the actual flying didn't coincide until the late 1800s, and heavier-than-air powered flight didn't occur until the Wright Brothers' success in 1903. Within a few years, stunt fliers were everywhere, and spectators were eager to watch them fly — and crash. Typical was Cal Rodgers, a cigar-smoking daredevil with less than 60 hours in the cockpit, who in 1911 became the first pilot to fly coast-to-coast. It wasn't easy. His wife, his mother, and three mechanics followed him across the country in a special

train, carrying $4,000 worth of spare parts. On the second leg of his trip, Rodgers ran into a tree just after takeoff. Ultimately he made 67 more stops on the way from New York to California; 19 of them were crashes. Once, he collided midair with an eagle. During the trip, repairs consumed enough spare parts to build four airplanes, and at the end of the journey only the rudder and two wing struts remained of the original. Rodgers needed repair as well: He had one leg in a cast and a nasty scar on his forehead. Four months later Cal Rodgers was killed while making an exhibition flight.

In spite of the risks, men (and soon, quite a few women) saw aviation as a compelling challenge: to fly farther, higher, faster, longer. Advances in aerodynamics merged with the ability to build stronger, more powerful engines and airframes, and pilots refined the skills required to fly them. Navigation and radios made long journeys more predictable. The developments of the jet engine and the swept wing complemented one another (the full potential of each couldn't be realized without the other), and the age of passenger jet travel was born. In the course of 75 years, flying went from the most hazardous means of travel to the safest — statistically several times less risky than strolling across a street.

Still, the challenge of flight beckons. Man continues to dream, and to fly — higher, farther, faster, longer. Whether the horizon is in the planets or the stars, whether the challenge is measured in duration, speed, or means of locomotion, flight continues to intrigue and coax us.

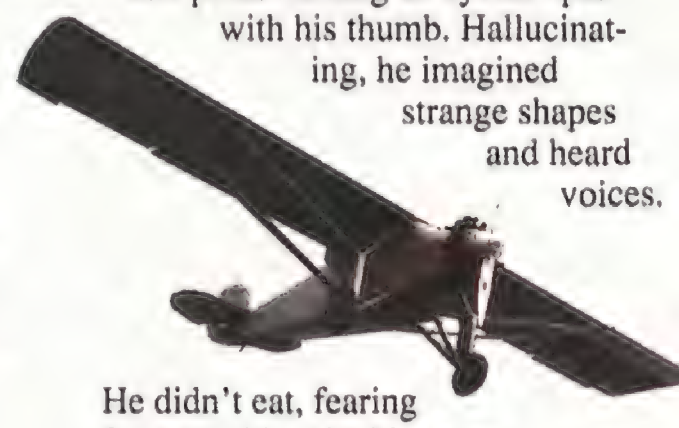
The 12 Firsts in Flight presented here have been carefully chosen. Naturally, any such list is arbitrary. Readers are encouraged to argue this point, and nominate substitutions of other worthy Firsts. But consider this: All but two of the events reported here occurred within the last 100 years. If man has achieved this much in so little time, what must the next century hold?

and the king relented. A straw fire provided plenty of lift for the 1600-pound balloon, but sparks burned holes in its sides, and the two Frenchmen spent the flight nervously dabbing at flames with damp sponges before landing safely. Ten days later, two more Frenchmen piloted a hydrogen-filled balloon on a two-hour, 27-mile journey from Paris to the French countryside. The balloon era had begun.

Photography Credits:
Michael Freeman / Spirit of St. Louis
Edward Turner / B-17
TASS from SOVFOTO / VOSTOK I
Chuck O'Rear / Daedalus

bicycle shop in Ohio, were cautious and methodical. Mostly self-taught, they watched birds and studied existing theories of flight (including Lilienthal's) before making a small "kite" glider in 1899. For the next three years the brothers tested full-sized gliders, traveling to the Atlantic shore near Kitty Hawk, N.C., where winds in autumn (the bike shop's off season) were strong and steady. To learn more about wings and controls they built their own wind tunnels and rewrote many theories of lift and control; for their first powered flight, they built their own gasoline engine. Twice during late 1903, rival pioneer Samuel Langley tried to beat the Wrights, launching his plane by catapult from the roof of a houseboat on the Potomac river. Each time it fell awkwardly into the water. Ironically, less than an hour after the Wright brothers' four flights on December 17, their empty plane was overturned by a gust of wind and was all but demolished.

and with only modest backing, was given a slim chance. But his rivals had terrible luck — squabbles and training crashes kept them on the ground. Six were killed. Weather was awful. When the storms lifted, Lindbergh hadn't slept all night. In a dawn takeoff in the rain, he barely cleared the power lines at the end of the field. His plane had only one engine, one seat (wicker), minimal instruments, no radio, no parachute; this saved weight, he said, so he could carry 2,500 pounds of gas for the 3,600-mile flight. All across the Atlantic Lindbergh fought sleep, at one point holding an eyelid open with his thumb. Hallucinating, he imagined strange shapes and heard voices.



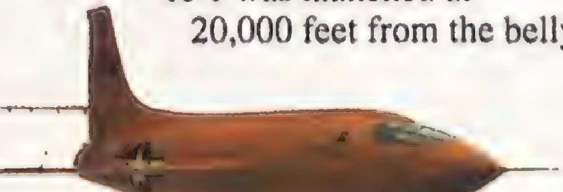
He didn't eat, fearing food would make him even sleepier. At last, he saw small boats (real ones) and then crossed the Irish coast. Five hours later, he was over France, then Paris. The crowd mobbed him, calling him Lucky Lindy. Two weeks later, one of Lindbergh's competitors flew nonstop from New York to Germany — 300 miles farther, and carrying a passenger! No matter. Lindy was first.

VISION is sponsored and produced by The Boeing Company. It is published for students and others interested in science.

Our own history of flight includes the first Boeing airplane (1916), the first U.S. international airmail (1919), the world's most popular airplanes (the 727 and the 737), and the world's largest passenger jet (the 747). We also built the Saturn booster used on Apollo moon missions, the Lunar Rover, and ing, aerospace, electronics, and While much of our franchise is for this publication is education alike find VISION helpful. Tell

VIS

shock "echoes" that bounced off wind tunnel walls. To test the barrier, the X-1 was launched at 20,000 feet from the belly



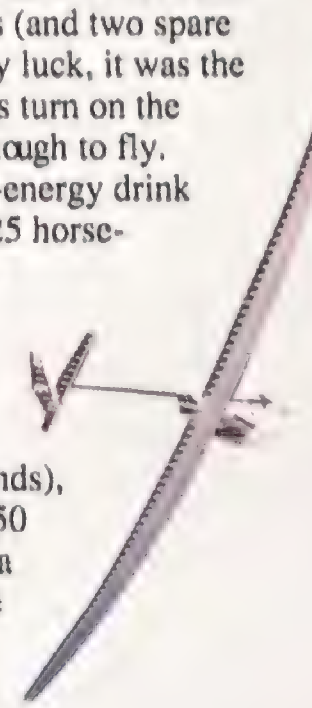
of a B-29. Yeager climbed to 42,000 feet (sound travels more slowly at higher, colder altitudes). The stub-winged plane shook as it reached 660 mph, then smoothed out as it passed the speed of sound. All airplanes create "waves" as they push through the air. Mach 1 (named for Austrian physicist Ernst Mach) was not a barrier at all, just a transitional speed at which an airplane catches up with its own waves, creating drag and turbulence. From these and other tests, designers created aircraft that slip more easily through Mach 1, using thin or swept wings, slender profiles, and special contours. These planes include the X-15A-2, which still holds the record for winged flight (Mach 6.72 — 4,534 mph — set in 1967), and the Concorde, which since 1977 has made daily Mach 2 passenger trips between Paris/London and the U.S.

following month, Alan Shepard flew America's first 15-minute suborbital mission. Both men essentially were passengers, their flights controlled by computers. But Gagarin and his colleagues had insisted on manual controls in the capsule, in case computers failed. So did American astronauts, and in 1962, on the first U.S. orbital flight, John Glenn had to wrest control from the computer and fly the reentry himself, thus proving the value of the pilots' demands. Gagarin's background was the stuff of Russian myth: born on a collective farm, son and grandson of peasants, builder of model airplanes, vocational school student, member of a flying club. Even his space flight had proletariat flavor; after the 89-minute orbit, he and his scorched Vostok ("East") capsule landed in a Russian pasture, where he was welcomed by three peasants and a cow. Gagarin never flew in space again, becoming a political figure and roving ambassador. Tiring of this role, he went back into training for another space mission and was killed in an airplane crash in 1968.

powered Flight Becomes Reality

A Greek cycling champion is both pilot and engine for the 74-mile flight of the Daedalus *from Crete across the Aegean.*

As in Greek myth, this flight was powered by a single human. But instead of feathers and wax, these wings were made of Mylar and polystyrene foam, built by a team from MIT in a three-year project costing $1 million. The ground crew of 36 included five pilots (and two spare airplanes), and by luck, it was the sole Greek pilot's turn on the only day calm enough to fly. Swigging a high-energy drink and generating .25 horsepower, Kanellos Kanellopoulos pedaled the 68-pound plane, plus his own weight (150 pounds), skimming 30 to 50 feet above the sea from Crete to the island of Santorini in just under four hours. (The previous record for man-powered flight — 22.3 miles across the English Channel — had stood since 1979.) Technically, the Daedalus legend says the ancient Greek landed in Sicily, but the MIT team proved a man could expend the energy needed to fly long distances. Like many of man's early dreams of flight, the Daedalus myth was finally realized.



dreds of major systems in comput-
tary and commercial aviation.
aking things that fly, our purpose
Ve hope teachers and students
vhat you think — we're listening.

The *Next* 12 Firsts in Flight

What's in the future? Hypersonic planes? Transporter beams? Mind travel? If you were preparing this poster for publication in the year 2090, what 12 significant firsts would *you* choose? Send your ideas to VISION, c/o The Boeing Company, MS 10-99, P.O. Box 3707, Seattle, Washington 98124.

I O N

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N-X-211
VISION

GEORGE STEINMETZ

Golden Gate Bridge, San Francisco

Honolulu

The Rides of March

March 1	New York City - London*
March 6	London - Hamburg
March 7	Hamburg - Berlin Berlin - Frankfurt Frankfurt - New Delhi
March 9	New Delhi - Frankfurt Frankfurt - Moscow*
March 10	Moscow - Frankfurt* Frankfurt - Istanbul
March 13	Istanbul - Frankfurt Frankfurt - Budapest
March 14	Budapest - Frankfurt Frankfurt - Warsaw
March 15	Warsaw - Frankfurt
March 16	Frankfurt - Nairobi
March 19	Nairobi - Frankfurt Frankfurt - Athens
March 21	Athens - Frankfurt Frankfurt - Paris (via local airline)*
March 23	Paris - New York City
March 24	New York City - Rio de Janeiro
March 26	Rio de Janeiro - Miami Miami - San Francisco
March 28	San Francisco - Los Angeles Los Angeles - Honolulu
March 29	Honolulu - Los Angeles
March 30	Los Angeles - New York City
March 31	New York City - New Orleans
April 1	New Orleans - New York City
April 2	New York City - Washington Washington - New York City
April 3	New York City - St. Maarten
April 8	St. Maarten - New York City*

**Airfare paid by passenger*

Cooking lesson with Paul Prudhomme, K-Paul restaurant, New Orleans (opposite, top)

Turkish bath attendants, Istanbul (left)

Water buffalo team, Taj Mahal, Agra, India

Postflight Wrap-Up

Cities toured: 16

Airports waited at: 21

Flight time: 136 hours 58 minutes

Air miles logged: 58,610

Average miles flown weekly: 10,522

Average speed: 472 mph

In-flight movies watched: 16

Bags of peanuts consumed: 74

Seat belt announcements heard: 66

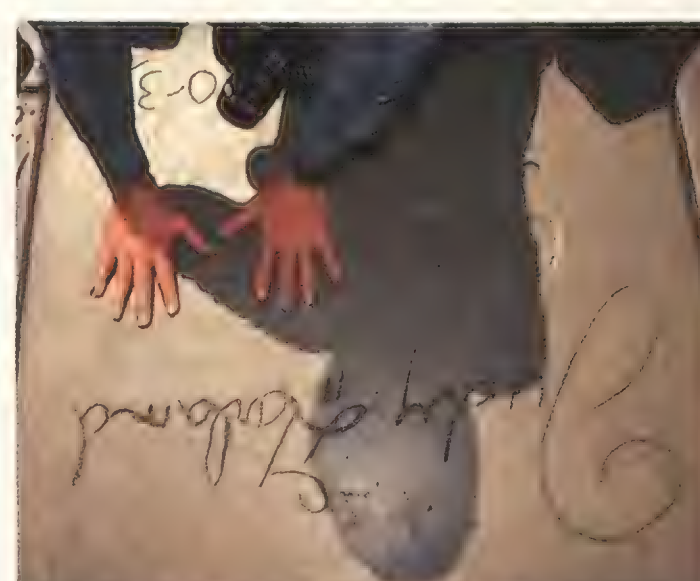
Times carry-on luggage was X-rayed: 54

Complimentary soap bars collected: 70

Times watch was reset: 24

No. of currencies in pocket simultaneously: 7

Dollar value of WorldPass 30 flights: $27,727



Mann's Chinese Theater, Hollywood

itself. It has a disco, three porn theaters, a supermarket, a bowling alley, and a detention center. You can go to a dentist, visit a museum, or drop your child off at a nursery. Tourists come from all over Germany just to get a look at the place.

Halfway through my journey I was running into flight attendants I'd met before, though for the life of me I couldn't remember where. Gazing out a cabin window at cruising altitude, I was often unsure whether what I was seeing was a sunset or sunrise. Once the body clock is sufficiently deranged you give up trying to get a good night's sleep and just

Over the Pacific: first-class accommodations, Pan Am 747

GEORGE STEINMETZ

Red Square, Moscow

settle for a catnap whenever you can.

At Nairobi's Jomo Kenyatta International Airport an A310 Airbus captain invited me into the cockpit. "It makes other planes all look like Model Ts," he said proudly. Computer screens have replaced instrument faces and an electronic voice announces altitudes on approach. "Want to go to the North Pole?" He punched in our present coordinates, destination, and winds aloft, and immediately the flight time, fuel needed, and best routing appeared on the display. Another pilot stuck his head in the cockpit. "I hear you A310 pilots can't fly for nothing," he said, "but you can type 80 words a minute."

During the longer flights I'd pace the length of the cabin for exercise and chat with the flight attendants. I once asked how we passengers appear to the cabin crew. "When I walk down the aisle, I see little chickens looking up with their tongues hanging out, waiting to be fed," an attendant told me. "They eat, and hopefully they sleep."

I was a well-behaved little chicken, eating my Sevruga caviar, medallions of veal, and soufflé Grand Marnier. I wasn't with the riffraff coach chickens but reclining in a spacious sleeper seat in first class. In addition to the perks, first-class seating made it easier to maintain my health. Cabin air is as dry as the Gobi Desert, so passengers need to drink plenty of liquids to prevent dehydration. There was always a flight attendant nearby to bring me juice, and the wide seats were conducive to dozing. But even in first class, there's not much you can do to prevent your feet from swelling up or your ears from popping.

On the ground, keeping myself in clean clothes was a major problem. The few times I tried to wash my clothes in a hotel room they were still soggy by flight time and had to be packed in a plastic bag. When I asked a Warsaw cab driver to take me to a laundromat we ended up at a butcher shop. I finally bought new socks—it was cheaper than having them washed by the hotel staff.

As I neared the end of my whirlwind tour I lost track of where I'd been and where I was going. So many different currencies jangled in my pocket that I listed to one side as I walked. At the Kapalicarsi market in Istanbul I simply held out a handful and let the shopkeeper pick out what he wanted.

I'm probably one of the few people who for one month have seen most of the world from six miles up. My only disappointment was that none of the nearly 60,000 miles I logged counted toward new frequent flier mileage.

The Performer Th

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The Rescue of Salyut 7

Almost every cosmonaut bears the title "Hero of the Soviet Union." There are heroes, and there are heroes.

by Saunders B. Kramer

Paintings by Andrey Konstantinovich Sokolov

As the Soviet winter reclaimed the land early in October 1984, three cosmonauts—Leonid Kyzim, Vladimir Solovyev, and Oleg Atkov—were making history in a tiny laboratory orbiting 230 miles above. They had left the Soviet Union while the previous winter was loosening its hold. Their mission lasted 237 days, at the time the longest period human beings had ever worked in space, but it received little attention outside the Soviet Union. By the end of 1984, those of us in the West who monitor the Soviet space program had come to expect the productive, long-term missions that followed one after the other on the Salyut space stations. Thirty-one spacecraft had docked with Salyut 6 during its five-year orbit, and when Salyut 7 was launched in April 1982, the process of sending crews to a station and resupplying them with unmanned cargo ships had become as routine as the seasons.

By 1984, the Soviets had conducted an immense amount of scientific research in the tight quarters of Salyut 7. They had photographed farmlands and identified 87 likely gas and oil deposits in the Soviet Union with a multi-spectral camera similar to that on Landsat; grown peas, oats, and onions aboard the station and proved that high-order plants could develop seeds in microgravity; manufactured semiconductor crystals for their electronics industry and biologically pure substances for medicine; and collected data on how humans react to prolonged stays in space.

At the end of their mission, Kyzim, Solovyev, and Atkov, the sixth crew to inhabit the tiny outpost, packed up film, tapes, and experimental data to bring back. Just before they left for home, Kyzim and his crew set out the traditional Russian gift of bread and salt for the next crew. They, like all of us here on Earth, expected their replacements to arrive before the following March. But the crew didn't come.

Sometime early in February 1985, Salyut 7 suddenly stopped responding to messages from Earth. Radio operators like those in the British Kettering Group, who regularly monitored the tracking beacons from Salyut 7, stopped hearing them. On March 2 the Soviet news agency Tass announced that work aboard Salyut 7 had been completed. The bulletin, noting that the station had been in orbit for almost 34 months, stated that "a vast amount of research and experimental work in the interest of science and the national economy was carried out. As the planned program of work aboard the Salyut 7 orbital station has been fulfilled, the station has been mothballed and continues its flight in an automatic mode."

Although readily acknowledging Salyut's success, Soviet space experts in the West were skeptical of this explanation for its sudden silence. We had grown accustomed to the guarded descriptions of space shots issued by Soviet officials. When they launched a satellite, they specified its orbit but not its mission. When they launched a manned spacecraft, they described the mission only in the most general terms. The Soviets still don't give most of their satellites names that indicate their purpose. They simply call them "Cosmos" and assign them a number.

To solve the puzzle of Salyut 7, we tried to piece together what we knew about previous Soviet practices in space. Salyut 6 had stayed in orbit two years longer than Salyut 7 had by that March and had hosted nearly twice as many crews before its retirement. And since Salyut 6 was maneuvered to a controlled reentry only after Salyut 7 had been launched, we had expected that Salyut 7 would remain active until its replacement was ready.

In addition, the Moscow World Service had announced just two months earlier that 1985 would see "plenty more" activity aboard Salyut 7. If the mission had really been fulfilled, I wondered why the term "mothballed" had been used instead of an expression indicating that the station would be retired. Those of us who could observe the station from the ground knew that Salyut 7 was either not tumbling or tumbling too slowly for the movement to be observed during the eight minutes the station was visible in each orbit from any one site. Nevertheless, we suspected that something had gone wrong—that an earlier repair of a propulsion unit had not been successful, that some electrical malfunction had disabled the spacecraft, or worse, that there had been a fire aboard. Five months later we learned that we were right about our misgivings. But at the time, even the Soviets didn't know what had happened.

For most of February the Soviet space community had wrangled with the problem of Salyut 7. Soviet ground control must have tried everything to regain contact with the station, but by March officials realized that the spacecraft was un-

Soyuz T-13 draws close to Salyut 7 and history. Docking with an uncontrolled craft had never been done before.

reachable and therefore uncontrollable. Mission directors, ground control personnel, flight directors, program managers, and specialists for every system aboard Salyut 7 met in Moscow to determine whether the space station could be saved. During long and sometimes emotional meetings, two factions formed. One group wanted to send a crew to inspect the station. They argued that the loss of Salyut 7 would mean the loss of the international prestige that the cosmonauts and mission support staff had worked so hard to achieve with their space stations. No doubt they reminded the assembly that when Skylab plummeted through the atmosphere in 1979 with some large pieces intact the Soviets had criticized the United States. A much smaller spacecraft, Salyut 7 would break up on reentry and most of it would probably disintegrate, but there was no assurance that a heavy structure would not reach Earth, and no capability to predict where it would land.

The opposition countered that the loss of prestige would be even greater if the Soviets attempted a rescue and failed. A manned mission, they argued, would needlessly endanger the lives of cosmonauts. The designers of the Salyut power system expressed serious doubts that power could be restored even if the reason for its loss could be determined.

The two groups debated whether the technical obstacles to a rescue mission could be overcome. The Soyuz ferry would be attempting to dock with an uncontrolled spacecraft four times its weight. Ground control could give no commands to the Salyut and could receive no information from it, but communications experts were confident that they could precisely fix the station's position for a docking attempt by using a technique called "skin tracking"—bouncing a radio signal off the spacecraft itself and confirming its position by the return beam. It should be possible, then, to place the Soyuz in the proper orbit for rendezvous with Salyut 7.

The changing distance between the station and the approaching Soyuz would have to be measured accurately enough to enable the crew to guide the ferry correctly. The radar system that the Soviets had used in the past is accurate only until the docking craft draws close. Within a distance of several dozen feet, the radar is almost useless. However, Soviet scientists had recently measured the distance between the moon and Earth to within six inches by using lasers. The Soyuz ferry could be equipped with a laser rangefinder that would measure the distance to Salyut 7 within three-quarters of an inch.

The Soviets were almost certain the station would be tumbling by the time a rescue mission could begin. Proponents of the rescue argued that it would be possible to determine precisely the rate of movement around all three axes and to imitate the yaw, pitch, and roll rates by giving manual commands to the Soyuz propulsion system. This procedure was considered very risky, however. Any difference in the rate of movement between the two spacecraft during the actual docking could cause the docking mechanism to break or could seriously damage the ferry and endanger the crew.

Many still questioned whether the cosmonauts, even with the best information, could manually guide their craft to a safe docking. From their position in the Soyuz, the crew can see a docking target only through a periscope that extends from the bottom of their craft and presents a view similar to that afforded by a periscope on a submarine. The more conservative members of the discussion group could point to several failures in docking maneuvers that had embarrassed the Soviets in the past. In 1976, Soyuz 23 didn't get close enough to Salyut 5 for the manual phase to begin. The following year Soyuz 25 reached Salyut 6, but the docking mechanism failed. The mission was scrapped, and the Soyuz returned to Earth two days after launch. During the Soyuz T-8 mission in 1983, the ferry's radar antenna failed to deploy. The commander tried to fly the Soyuz manually but decided he was unable to judge the distance accurately; fearing a collision, he maneuvered the spacecraft away from the Salyut. However, in 1982 Vladimir Dzhanibekov had taken control of Soyuz T-6 and completed the docking maneuver when the automatic system failed.

The cosmonauts had to leave behind the light and warmth of the Soyuz to work in the tomb-like station.

At some point, the Soviets must have realized that future stations would be endangered if they didn't learn what had befallen Salyut 7. They decided to attempt a rescue. Their decision to go ahead despite the hazards shows their commitment to the orbiting laboratories. It is also evidence of the confidence they had gained in their abilities in space. The Soviets were not ones to risk humiliation. They believed they could do it.

As soon as the decision was made, Alexei Leonov, deputy head of the Cosmonaut Training Center, paid a visit to Vladimir Dzhanibekov at his apartment in the cosmonaut community known in the West as Star City. Leonov found

Dzhanibekov and his family discussing plans for the coming weekend over tea. A veteran of hazardous missions and the first person to walk in space, Leonov knew the risks involved and broke the news abruptly. "Vladimir, you start the physicals tomorrow," he said. Dzhanibekov later wrote in an article for *Parade* magazine that he knew what the mission was before Leonov said anything further. Star City had been humming with discussions of the space station for weeks.

When he manually docked the Soyuz T-6 spacecraft with Salyut 7 in 1982, Dzhanibekov was already a space veteran. He had commanded Soyuz 27 in 1978, the first mission to dock three spacecraft in orbit. He had commanded a second mission to Salyut 6 in 1981. On his fourth mission he docked the Soyuz T-12 with Salyut 7. The rescue mission would be his fifth. Still, he must have dreaded the chore facing him. Imagine trying to attach the 23-foot ferry to a slowly tumbling object the size of a railroad car that you can see only as a reflection on a screen. You have only one place to make contact and probably only one chance. Your ship is so fragile that even a light collision, the result of a false move or a bad decision, could damage it enough to imperil the crew. Finally, directions from the ground won't help; you must rely on your own skills and judgment.

Viktor Savinykh, who had worked with Dzhanibekov on Salyut 6 in 1981, was selected to accompany him. Although the Soyuz T spacecraft can accommodate three cosmonauts, the Soviets decided to go with two and send extra supplies of air, water, and food instead of a third person.

For more than three months, the crew trained for their mission, simulating dozens of repair procedures. The Soviets believed that communications with Salyut 7 had ceased because of a malfunction in the power supply system, so the cosmonauts learned every wire and connection in the system. They practiced the unassisted rendezvous and docking with Salyut 7. One of the prototypes was submerged in a large water tank so the crew could practice in a simulation of weightlessness.

They were trained to use an instrument suite especially designed for the manual-approach maneuvers. The suite included a laser rangefinder, an optical guidance instrument, and a night vision device that would enable the crew to see the space station if rendezvous occurred while they were on Earth's night side.

On June 6, 1985, Soyuz T-13 lifted off from the Baikonur Cosmodrome, carrying the 57th Soviet space crew into orbit. After months of simulation, Dzhanibekov and Savinykh were on their way to rendezvous with the real Salyut 7.

Under normal circumstances, Soyuz crews orbited Earth 17 times in a 24-hour period before docking with the space station. The tracking beacon ordinarily broadcast by the station enabled ground control to determine its position accurately and then inform the crew when to activate the Soyuz propulsion system to make judicious, incremental alterations in their orbit on the approach to docking. In this instance, however, the less precise method of skin tracking and optical tracking from the ground stretched out the journey to Salyut 7 to two days and 33 orbits. During that time the crew conducted routine spacecraft checks and made two corrections to the spacecraft's path for the rendezvous.

In its 33rd orbit, the Soyuz pulled to within five miles of the station and was narrowing the distance at 40 feet per second. Ground control slowed the spacecraft to approach at about 20 feet per second. When the ferry was within a mile and half of Salyut, the crew took control.

At 160 feet from their target, Savinykh activated a television camera. While Dzhanibekov circumnavigated the station, the camera relayed images to a receiving station at Yevpatoria, on the Crimean peninsula, which in turn relayed them to the screen at mission control in Kaliningrad near Moscow. The mission control team saw in sharp detail the same desolate scene that the cosmonauts were seeing. "The station looks as if battered by savage storms," Dzhanibekov told them.

The once bright green exterior of Salyut 7 had faded to a grayish color. The solar panels were disoriented. The soft thermal coating was damaged. Although portholes had been shaded by curtains that hid the interior, the cosmonauts knew that the station was frozen and quiet.

The station tumbled slowly, ominously, without radio or radar response. Slowing his approach to several feet per second, Dzhanibekov activated the laser rangefinder and concentrated on the cross hairs in the optical guidance instrument. Savinykh steadily called out range and approach rates while Dzhanibekov used two control handles to give delicate commands to the propulsion system. Both men continually consulted a television monitor on which the Salyut loomed larger and larger as Dzhanibekov guided Soyuz T-13 into place.

The docking probe on the Soyuz entered the cone on the Salyut. The men felt a gentle thump and heard the mechanical clicks as three latches on the docking mechanism closed to connect the spacecraft loosely. (Later Dzhanibekov would say, "Docking is like driving a seven-ton truck with fragile freight on an icy road into a narrow gate at the end of this road.") Three more clicks and the vehicles were joined fast. The first danger was past. The cosmonauts undoubtedly breathed a little easier. But still in a precarious position, they concentrated on following procedures.

The thin layer of frost that covered portholes, wires, and instruments made hopes for recovery dim.

Using pressure gauges, Dzhanibekov and Savinykh made sure the seal between the two craft was tight. They then used a special device to test for toxic gases that could have been produced by a fire aboard the station. They found no sign of toxicity, but both crew members donned gas masks as they prepared to enter the docking compartment.

After they equalized the pressure between the two spacecraft, the cosmonauts slowly opened the hatch on the Soyuz module, swinging it inward; then they opened the transfer compartment hatch. They inspected the compartment quickly, then moved with caution to the hatch separating them from the main module of the Salyut station. They opened the inner hatch and floated into darkness and still, cold air. "In the absolute quiet," Dzhanibekov later said, "I could clearly hear my heart beating."

No currents stirred except those created by their own movement. They could see only where the small circles of light from their flashlights fell. There was no sign of an accident or fire, and the men cautiously removed their gas masks. They had been accustomed to the whirring of fans, the humming of the environmental control system, and the intermittent firing of attitude control rockets, but the station was eerily silent. The green, yellow, and red lights of digital instrument readouts were all dark.

Dzhanibekov and Savinykh moved to the windows and drew back the curtains. Beams of sunlight revealed the packages of bread and salt left by the previous crew. The portholes, walls, and instruments were all covered with a thin layer of frost. "We had a real predicament on our hands," Dzhanibekov realized. "Most onboard systems, we knew, can only work at room temperature, not in a frigid atmosphere like that in which we found ourselves."

When the cosmonauts entered the compartment, the temperature was below freezing. The mission planners, anticipating the frigid temperatures, had equipped the cosmonauts with fur-lined suits, gloves, and hats specially designed for the trip. The men also wore heavy boots and extra socks, but the cold would make their work very difficult.

The cosmonauts confirmed what the disoriented solar arrays had led them to assume: no power was available. They checked the lights and the heating system. Nothing responded. Their flashlights showed the voltage readings for the batteries—all read zero. They then returned to the Soyuz to contact ground control.

According to later accounts by Konstantin Feoktistov, a cosmonaut and specialist in spacecraft design, the report from the cosmonauts to ground control convinced power specialists that they had been right: the system was beyond repair. But having faced the dangers of the journey, Dzhanibekov and Savinykh insisted on trying to revive the station. Ground control agreed, but instructed the cosmonauts not to connect Salyut 7 circuitry to Soyuz T-13. A mishap could cause the Soyuz to lose power as well.

The first task was to hook up a ventilation system from the Soyuz to circulate air and supply fresh oxygen. The system would enable the cosmonauts to work in the station without being poisoned by the carbon dioxide from their own breathing. Once the air was circulating, the cosmonauts turned their attention to the power supply.

The Soyuz T-14 (far right) remained attached to Salyut 7 for two months after the Soyuz T-13 departed.

The Salyut 7 is equipped with eight chemical storage batteries that are continually recharged by the solar arrays. The cosmonauts found that all eight batteries were dead and that two were faulty. According to Feoktistov, a charge-gauging device on one battery had failed. The device acts as a limit switch that prevents the battery from supplying power when its charge drops below a certain point. When the switch failed, the battery drained completely and functioned as a resistor, keeping the power from the solar arrays from reaching the other batteries. The continued use of power stored in the remaining batteries drained them as well, and gradually each station system shut down. As the power specialists had realized, power from the solar batteries could not be restored without power from an outside source.

Under instructions from ground control, the cosmonauts discarded the two faulty batteries and connected the other six directly to the solar arrays. Materials for the cabling arrangement, which they laboriously constructed with step-by-step

checks with ground control, were cannibalized from the station. The work was slow. Because the station was so cold Dzhanibekov and Savinykh retreated hourly to the Soyuz for warmth and rest. Only then could they communicate with ground control. Once they received instructions, they traveled back to the lifeless station to implement them.

After the cosmonauts established the circuitry, they used the control and propulsion systems of the Soyuz to rotate Salyut 7 so that its solar arrays faced the sun and could begin to collect energy. They also interrupted most electrical connections between the batteries and the station's systems in order to give the batteries a chance to charge fully before being used to supply power.

After a full day of clambering back and forth between the two spacecraft and fumbling with wires through awkward gloves, the two men huddled at the voltage indicator and watched the needle tremble, move off zero, and very slowly rise. Some hours later lights were available. Finally they reconnected the fans, and the station started to feel again like a place to live and work, although the air was still freezing. To get a warm meal, the crew created a makeshift oven. They insulated their camera bag with a towel, inserted a lighted photo bulb in the middle, and warmed food packages and containers of coffee and tea.

The cosmonauts soon discovered that some of the Salyut's instruments for radio communication with mission control were also faulty. They replaced them from stores on board, and after more than four months of silence, mission control received signals from Salyut 7. Director Valeri Ryumin, a cosmonaut himself (the first to accumulate a year in space), said that the sight of the data was so pleasing that he was able to sleep soundly that night for the first time in weeks.

Over the next 10 days, Dzhanibekov and Savinykh checked every one of the hundreds of wires, cables, and instruments on the space station. While they performed the tedious work, they were subjected to the additional stress of rationing water. They had brought an eight-day supply, thinking that they could rely on the water stored on the station. The Salyut water tanks remained frozen solid, however, until the 11th day. By then the ice that had accumulated on the pipes and windows had melted as well. The crew ran out of paper towels trying to mop up all the moisture and had to resort to whatever was available, including napkins and old underwear.

Two days later, according to Feoktistov's report, "a test of the station's orientation system, rendezvousing apparatus and propulsion engine assembly was successfully conducted." The Salyut 7 could operate on its own.

The repairs and thorough examination had been an ordeal for the two cosmonauts. "The main thing in such operations," Dzhanibekov later commented, "is not to give way to nerves, although weariness gradually builds up into irritation—sometimes with yourself, sometimes with those trying to help you from the ground. You simply have to be able to pull yourself together in the face of setbacks and mishaps."

An unmanned resupply ship, Progress 24, docked with the reclaimed Salyut 7 on June 23. It delivered three new sets of chemical batteries (which the cosmonauts immediately installed), drinking water, food, replacements for failed instruments, new equipment for experiments, and fuel for the Salyut engines. It also brought letters, newspapers, messages from the families of the two cosmonauts, and audiotapes of rain, rustling leaves, and birds singing.

The Salyut resumed its productivity. At the end of June, the huge multi-spectral camera that had become valuable to Soviet agriculture by helping to predict crop yields was reactivated by the crew. On September 18, Soyuz T-14 arrived with three cosmonauts to take over experimentation and observations. Dzhanibekov returned to Earth on September 26, while Savinykh remained on board with two members of the new crew. They all returned, rather suddenly, on November 21 when one member became severely ill.

The following February the Soviets launched Mir, their eighth station. Salyut 7 was moved to a higher Earth orbit on August 21, 1986, where it remains, this time truly "mothballed." The Soviets say they are considering an expedition to retrieve the station in order to study the condition of the structure and equipment. A technical study group is now determining when and how Salyut 7 might be returned to the U.S.S.R. on the Soviet space shuttle *Buran*. If they follow through with their plans, Salyut 7 may have still more to teach us about surviving the hazards of space.

Why Mars Should Be Earth's Next Goal

Oleg Borisov
Scientific Analyst
Novosti Press Agency

On Mars we can proclaim humankind a space civilization.

The number one priority of the Soviet space program for the next two decades is sending a manned expedition to Mars, and the odds are improving that we could find evidence of past life upon our arrival. Phobos 2 detected an unexpected diversity of surface materials—additional signs that Mars still has some surprises in store. We are calling for an international effort for this mission in the hope that the United States and other nations will join us. A joint mission would promote the idea of living in peace and would introduce humanism, respect, and mutual understanding into international relations. The new data from Phobos 2 could be seen as an important boost toward a joint mission.

The Soviet Institute of Space Research of the Academy of Sciences gives four reasons why Mars is so attractive to scientists:

(1) Mars is similar to Earth. The Martian day, at 24 hours and 37 minutes, is only slightly longer than ours; the planet has an axis tilt that creates seasonal variations similar to those here; Mars, like Earth, has a wide range of terrains; and the temperatures on Mars, although very low at night, are comparable to Earth's during the day. By studying Mars and using methods of comparative planetology, we will gain insight into the history and structure of our own planet.

(2) There is evidence that Mars has experienced an interesting evolution of its climate and surface. Mars may once have had open bodies of water and a dense atmosphere. If so, we must learn why they disappeared.

(3) Mars is a prime candidate for extraterrestrial life, past, present, or future. Even if we find only the simplest form of life, it would revolutionize our world outlook and understanding of the origin of life on Earth.

(4) Mars, the only potentially habitable planet in our solar system besides Earth, is the first planet on which we can land and proclaim humankind a space civilization.

The Soviet program will include three phases. The first, planned for 1994–1996 and based on use of the Energia booster, will study the Martian surface and atmosphere using unmanned rovers, drilling units, balloons, and an orbiter that will survey the planet's surface from an altitude of 125 to 190 miles.

All the groundwork for the future manned mission will be done during this phase, including choosing sites of maximum interest to future crews. Scientists are interested in the history and geological structure of Mars. Craters, valleys, and volcanos will be examined closely for evidence that water was once plentiful on the Martian surface. Mariner 9 established that liquid water can exist on the Martian surface for only short periods—yet its cameras also revealed clear evidence of water erosion.

The unmanned rovers, powered by radioisotopes that will give them a lifespan of one to three years and a range of 300 miles or more, will be equipped with mini-labs that can analyze soil samples. The balloons, inspired by those successfully used in the Venusian atmosphere, will carry cameras that will be able to discern, from an altitude of 650 feet, details of the surface as small as a tennis ball. The balloon probes may last about two weeks in the thin Martian atmosphere and send back hundreds of millions of bits of information. For the first time man will have a bird's-eye view of the most remote parts of Mars.

The next phase, scheduled for 2000–2005, will be a rehearsal for the manned mission. The wide range of research tasks conducted during this phase will include more detailed studies by rovers. One lander will return to Earth with samples of Martian soil and polar ice for detailed physical, chemical, and biological analysis. Study of these samples may reveal whether water is still trapped in the subsurface permafrost. Soil taken from

Could Mars be keeping a secret that is vital to the survival of our fragile Earth?

anywhere on the Martian surface could also answer questions about the conditions that have persisted on Mars for billions of years and left it barren while life here on Earth flourished.

If the first two phases of the program are successful, the first manned mission to Mars will take place in 2005–2010. It will require a very large spacecraft because, in addition to carrying a million or more pounds of fuel, the ship must accommodate humans for as long as three years. Just to exist in space for one day, each crew member will need several pounds of oxygen, four pounds of water, and three pounds of food. Because of these weight requirements, it may be necessary to use nuclear electric engines. Although these engines are low in thrust, they are more fuel-efficient than liquid rocket engines, and most important, they can operate for hundreds of days on end.

Once the explorers arrive on Mars, they will encounter the Martian atmosphere, which is unfit for breathing and by Earthly standards very thin. It is made up almost entirely of carbon dioxide with traces of water vapor, and the atmospheric pressure near the surface is only 0.5 percent of Earth's. These conditions, as well as differences in temperature and gravity and the lack of water, will confine explorers of the Red Planet to spacesuits, special relaxation boxes, and well-sealed self-propelled vehicles.

The most exciting question for Mars explorers is whether the soil will reveal organic matter or traces of extinct life. Even though the U.S. Viking landers in 1976 turned up no positive signs of life, Lev Mukhin, a leading researcher from the Institute of Space Research, believes that these results were inconclusive, since the probes were of low sensitivity and examined only two small areas of the planet. New evidence collected by the Soviet spacecraft Phobos 2 in 1989 shows that the composition of the Martian surface is varied. This contradicts the finding of the two Viking craft, which determined that the soil at two sites was very similar.

There is reason to be optimistic about the possibility of life on Mars, even if life had existed only in the remote past. If the early climates of Mars and Earth were similar shortly after the planets' formation, sedimentary rocks in ancient Martian riverbeds would be an ideal place to hunt for fossils of organisms. There is even a chance that a living plant cell or a bacterium could be found in a specimen. Scientists would have mixed feelings of delight and concern over such a discovery because it would raise the serious issue of pathogenicity. The immune system of Earthlings may prove powerless against attacks by microorganisms of extraterrestrial origin.

A joint mission would bring the U.S. and the U.S.S.R. closer.

If a growing number of U.S. and Soviet scientists have their way, astronauts and cosmonauts will explore Mars together by the year 2010. Teams of engineers and scientists from both countries are planning unmanned missions for the 1990s, and there is a hope that politics will allow the two nations to cooperate in a joint mission that would help draw the Soviet Union and the United States closer. The consensus among many space scientists and leaders in both countries is that it is not only desirable to cooperate, it is necessary. The heavy financial burden of a manned expedition to Mars could be shared by the two countries instead of falling on one.

It would be easier to reach Mars than it was to reach the moon because no new technologies would have to be developed. We would only have to utilize those currently available. Traveling to Mars would be no more expensive than a major strategic weapons system. If shared by two or more countries the cost to each would be even less, and the possible benefits incalculable.

Higher Learning

This California school teaches students to look at flying through new eyes—those of a test pilot.

by Carl A. Posey

First you must ignore the ghosts of past instructors and their exhortations: *Its wings are your wings! Its body is your body!* Today the wings of this Cessna 150 are *not* yours, but its own. In fact the airplane is a kind of paradigm, a model to be looked at from the outside. Because on this afternoon, you are—dare you say it?—the test pilot.

Above the dry lakebeds of Antelope Valley, about a hundred miles north of Los Angeles, you are flying this airplane to see how the machine actually does what it does, and how well. The assumption is that the Cessna 150 is on its first flight and unencumbered by a handbook full of data—maximum rates of climb, takeoff and landing distances, and all its other param-

BERL BRECHNER (2)

eters are still undocumented.

Sitting beside you is Wendy Shawler, director of operations at the National Test Pilot School. Located in Mojave, California, it is the only civilian school in the world that specializes in transforming pilots and engineers into test pilots and test engineers. Shawler is demonstrating how to assess the airplane's performance. Its engi-

At the National Test Pilot School, students fly the Spectrum to gather data for its certification. Recognizing the need for civilian test pilot training, Seán Roberts (left) founded the school in 1981.

neers have aimed their design at Federal Air Regulations—FARs—which specify the minimum requirements for what aircraft must and must not do. You are checking the accuracy of their aim.

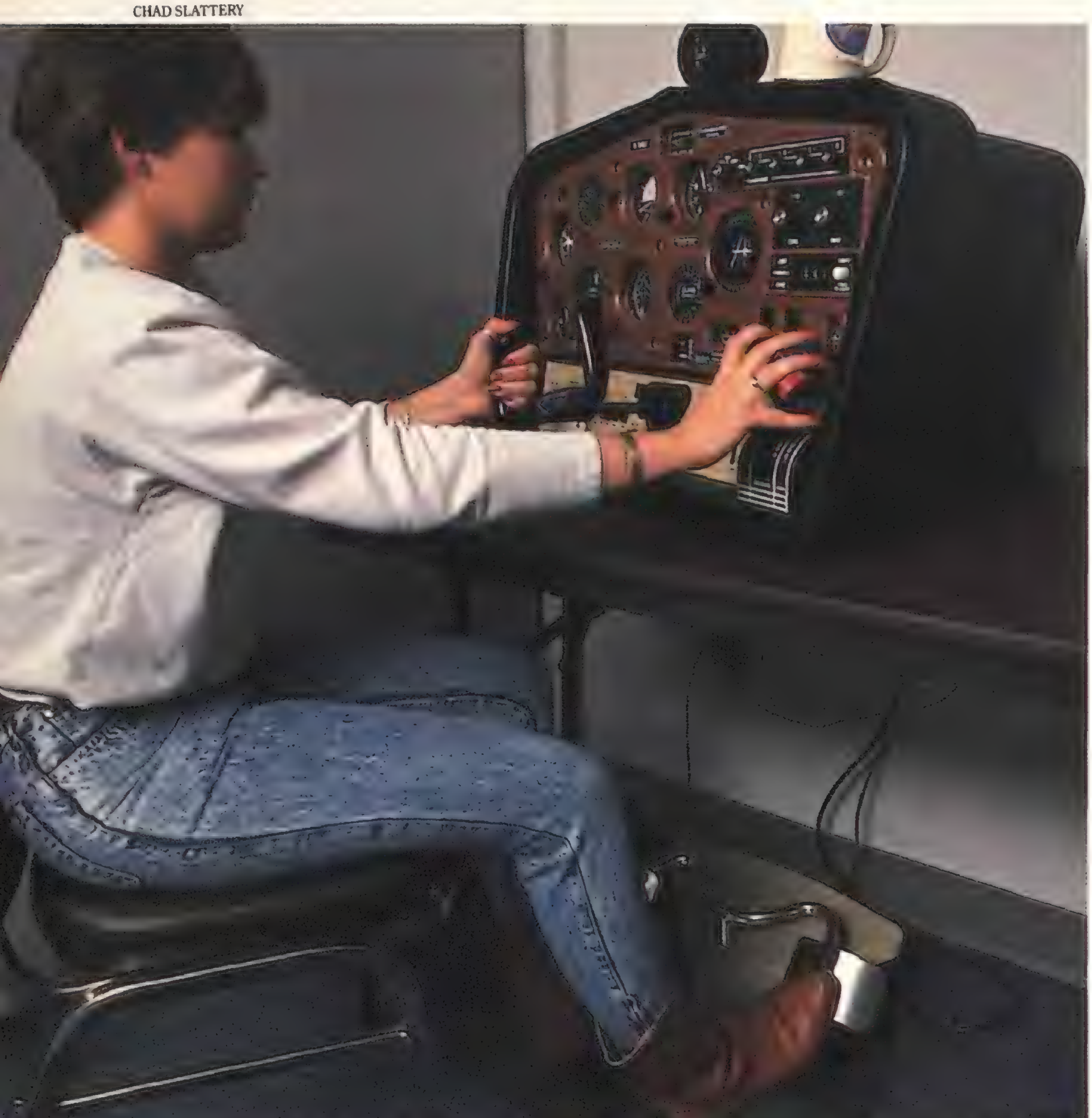
The idea, as Shawler puts it, is to determine through a series of very small incremental steps exactly how the airplane is behaving. Some rudimentary engineering changes have been made to this Cessna's controls so that besides merely flying, the pilot can monitor the dynamics of the flight as well. A stall provides a case in point. As test pilot your goal is to observe the maneuver from some external vantage point. At what speed does the wing first lose its lift? When does the airplane give its warning? How far aft can the center of gravity be shifted before the stall becomes horribly uncontrollable?

Flying an airplane from the outside is demanding work, even for a guest test pilot on a short flight. Irresistibly, your thoughts turn to what it must be like to do such work in airplanes of vast possibilities—which is exactly what a stocky young man nicknamed Joe was doing at this time last year.

Joe, whose real name is actually Vorachat Tharechat, came to Mojave from his native Thailand to go through the school's full, 11-month test pilot course. During his stay he wore his flight suit with Thai pilot's wings and the three bars of a squadron commander. Detailed to the Thai air force test center in Bangkok, he has an engineering degree and seven years' flight experience, much of it in Thailand's fleet of Northrop F-5Es.

Engineers can use the school's simulator to gain some basic flying instruction.

CHAD SLATTERY



Like most military pilots, Joe had been trained to fly airplanes within the manufacturer's performance envelope. In the hands of the NTPS instructors, he learned how to view flight from the external perspective of the test pilot—to envision the forbidden land beyond the envelope. "Pilots really don't have to unlearn anything," says Seán Roberts, the 54-year-old director of the school. "They just have to learn a different way to fly: much more precise, everything right on the money."

The Belfast-born director speaks from his office in the school's new building, a green and white structure completed in late 1987. "We find people with relatively little flying time can do it quite well," says Roberts, "and some high-time people can't hack it at all. Some of what I'd call good company pilots—good, safe ones—just let the aircraft drift around."

The transformation from pilot to test pilot occurs gradually over the 11 months of the course. In the beginning none of the incoming students knows how to evaluate an airplane and report on it. They may be able to fly it safely, but they don't have the technical skills to quantify its performance. Gradually they learn how to acquire data while flying and how to communicate it. It is not a sudden transformation, but the differences in a student's capabilities between the beginning of schooling and the end are dramatic.

Applicants to NTPS must have a technical degree and, if they want to be test pilots, must be aviators with a minimum of 1,000 hours of pilot-in-command flight experience. Civilian pilots must have twin-engine turboprop experience. The school prefers military pilots to have experience flying several military airplanes.

The schooling comes in four good-sized doses. It starts with four weeks of preliminaries, designed to make sure students have the basic academic and aeronautical qualifications for test pilot school, as well as the essential skill of being able to think and fly at the same time. "The guy who's a non-thinker doesn't have the ability to plan and think

in the air," says Roberts. "If you fly by rote, well, that's a killer. You also have to be able to pass on what your first flight has taught you, and you need to understand what's going on, so you can precisely and clearly report on what the airplane is like."

Next comes a three-month period of studying aircraft performance—in essence, how airframe and powerplant work together—and then three more months learning to evaluate the way the craft responds to its controls under various conditions. The final course, on systems, lasts up to four months. It focuses on the myriad complications that arise as complex avionics and weaponry are added. The classwork is punctuated with flight, and each student ultimately assesses an unfamiliar avionics system and an aircraft he or she has never flown before. A thesis project is the final requirement.

The school also offers a variety of other courses, including a version of the long course that has been compressed down to three months for engineers. Another two-week indoctrination course is intended to help trained engineers focus on the special needs of flight testing.

Joe was enrolled in the most demanding curriculum the school offers, and the most expensive. But even at $220,000 per pilot and $140,000 per engineer, it costs only a fraction as much as the Air Force and Navy test pilot schools, which run about $800,000 per pilot. It also offers training its alumni can use outside the military—to certify aircraft in accordance with both mission requirements and Federal Aviation Administration standards, for example.

Now back in Thailand, Joe is doing experimental testing on propfan jets and modified F-5s. But during his stay at NTPS Joe flew airplanes from a more eclectic squadron. The school's fleet consists of an aeronautical zoo of odd and extinct species of aircraft that, because of hair-straightening handling characteristics or some *je ne sais quoi* of beauty or bestiality, find a place in Roberts' ample aviator's heart.

"You want to give the students a broad spectrum of experience. Some planes have very good performance but bad handling qualities," notes Roberts, referring to how well an airplane flies compared with how easy it is to maneuver. "The Merlin, for instance, has fantastic performance but terrible handling. The Dove has lousy performance but great handling. The V-tail Bonanza's great but don't stall it. We prefer bad airplanes."

Besides the Merlin III twin turboprop and the de Havilland Devon, or Dove, which are equipped with instruments to measure performance and handling qualities, the school has a Beechcraft Queen Air equipped with instruments for systems testing. And in addition to a clutch of Cessna 150s and such button-down types as the Beechcraft Bonanza, there is a Morane-Saulnier MS 760A Paris I, a four-place French jet with the deep cockpit and soft-edged, handwoven look that marks the small craft of that country. Nearby is an Hispano HA-200 Saeta, looking ready to fight the wars of 40 years ago. The aerobatically dramatic de Havilland Chipmunks look positively mundane in such company. Waiting in the hangar is a Piper Cherokee with unusual flying characteristics due to its having spoilers instead of ailerons. The school also leases other airplanes—a Northrop T-38, a Lockheed T-33, a Lear 24, a Cessna Citation, and an Embraer Bandeirante from Brazil. For those who value discomfort, there are Decathlons and Pitts Specials available for inverted-spin training. A Sikorsky S-55 with instruments to measure performance and handling qualities now permits the school to extend its helicopter test training syllabus.

Although every course requires some flying, most of the time at Mojave is spent on the ground slogging through jungles of plotted data. In one classroom, senior pilot and instructor John Brown points out that, while performance curves are drawn today by computers, "there are millions of data points that come from flight tests that determine data for flight manuals, specifications, pilot technique, and other things," and these data points are unknown to computer models.

This afternoon the Dove is scheduled to fly. Some 30 years ago Roberts trained to be a test pilot in this very airplane, which now sits on the ramp wearing the placid expression of a contented insect. Nearby two uninstrumented Dove/Devons squat on the hot apron, and a fourth is parked near another hangar, cannibalized beyond recognition. The little flock is a second-hand shop for parts.

CHAD SLATTERY

BERL BRECHNER

NTPS instructor Dick Lawyer lectures Army students who hope to become test pilots (top).

Two Indonesian students compare notes at debriefing with instructors Victor Chou and Paul Young.

Like most airplanes modified for research, the Dove bristles with odd fixtures—wing tabs to show laminar airflow, a deployable pod used for towing sensors on a long wire from a housing under the fuselage, and various devices along the wings and fuselage to detect angle of attack, slip, and the like. These are connected to instrument consoles in the cabin, where students gather the data they later put into a computer to evaluate the airplane's performance and handling capabilities.

This Dove sortie is for four Army students from nearby Edwards Air Force Base who are scheduled for training at

the Navy test pilot school at Patuxent River in Maryland. The Army program is a source of considerable pride for Roberts. In 1976 three of the nine Army students were washing out of Pax River. "We told the Army, make up a class of 20 and we'll teach them," Roberts recounts. "Chances are we'll lower your washout rate." The result: "Our Army washout rate is zero."

The problem, according to one of the students, was the absence of a test pilot tradition in the Army to prepare its pilots for the rigors of the military schools. "They send us here first for evaluation, and also to bring us up to speed . . . about two years of calculus in a couple of hours," explains Warrant Officer Mark Metzger. The school is a critical career step. "My orders say: 'Should he fail, he's back in the mud,' " Metzger says, referring to himself.

Metzger has been flying mostly helicopters for the Army since 1972. "All my flying up to now has been to maintain control of the airplane," he explains. "Here you do the opposite: let the airplane do what it's supposed to do. You have to learn to take yourself out of the loop. They put you in uncomfortable situations to see how you do."

Aboard the Dove at 6,000 feet, Metzger and the three other Army stu-

BERL BRECHNER (2)

Roberts, in the cockpit, checks on students seated at the Dove's three instrument panels.

Built in 1952 for the British Navy, the Dove has sprouted odd fixtures and devices to measure its performance.

dents gather their afternoon's data. Wendy Shawler is in the lefthand seat, Roberts in the right. The two sit high up in the craft's insect-like eye.

Shawler flies the airplane through carefully controlled maneuvers one by one. The first maneuver is called a steady heading sideslip. It measures both lateral and directional stability. Roberts reads off numbers on the intercom. "Bank angle, eight degrees," he pronounces. With clipboards on their laps, the students record the aileron, rudder, and sideslip values that appear on the gauges. "Bank angle, 15 degrees," Roberts intones. The students take another set of readings.

The Dove switches back up the valley to begin a series of flat turns—a turn done without banking—to measure directional stability. This is followed by a wing pickup, a maneuver which measures lateral stability by using the rudder to level the wing.

The 45 minutes of data gathered on this flight will require about eight hours of number crunching on the ground. Using the resultant plots and graphs, the students will match the Dove against the FARs and decide whether it should be certified as meeting them or, if not, help develop engineering solutions that square it with the regulations.

BILL CASALE

Located at the east end of the Mojave Airport flight line, the school owns a fleet of 21 aircraft, including a Sikorsky S-55 helicopter.

That the world should have civilian test pilot training has been Roberts' unshakeable belief from the early days of his long flying career. "The military teaches you how to be military acceptance test pilots," he explains. "They're not trained to be company test pilots, to be put on the design team, no training for FAA certification. You have military specs and standards that recommend flying qualities for piloted aircraft. But in the military you think in terms of the mission. You can't throw out an FAR; it's the law of the land. But a military pilot has the option of waiving a spec that gets in the way of performing a mission."

A pilot with about 16,000 hours in "everything," Roberts was graduated from the Royal Air Force College of Aeronautics at Cranfield in the 1950s, and later trained in aero-engineering at London University. "I came over here," he says, "... and thought we needed a plane like the Dove. It was like being an auto engineer and not having a car to work with."

He ended up modifying an old twin Beechcraft at Mississippi State University and teaching courses for engineering students. He did the same thing at the University of Tennessee with a Cessna 310. At the University of West Virginia he modified a Cessna 206. While he was working as a contract instructor at the Air Force Test Pilot School at Edwards, the Dove became available and he decided to buy it and make housecalls.

In 1981 the school became a reality. It was inspired, Roberts explains, when the chief test pilots at McDonnell Douglas, Boeing, and Lockheed "came to me and said, 'We have a problem: we don't have the ability to send anybody we want to a military test pilot school at a cost of $800,000 per pilot.' Also, the manufacturers didn't want to lose people for so long." What they did want was an alternative training program, which they referred to as a manufacturers' test pilot school. Roberts started one, but hardly anybody showed up from the manufacturers. "When they wanted the school, they had time for training," he says. "Now they have the school but they don't have time for training."

Unexpectedly, the strongest interest came from overseas. Relying on the small cadre from the budding school and contract personnel drawn from the military and industries, Roberts had instructors training test pilots and engineers all over the world—Indonesia, Israel, South Africa, Brazil. "We were spending more time teaching abroad than here," he recalls.

But the logistics of teaching overseas were unforgiving. "Hard life for the instructors," remembers Roberts. "I was spending fewer than 30 days a year in the States for two years in a row, and much of the equipment in Mojave was standing idle."

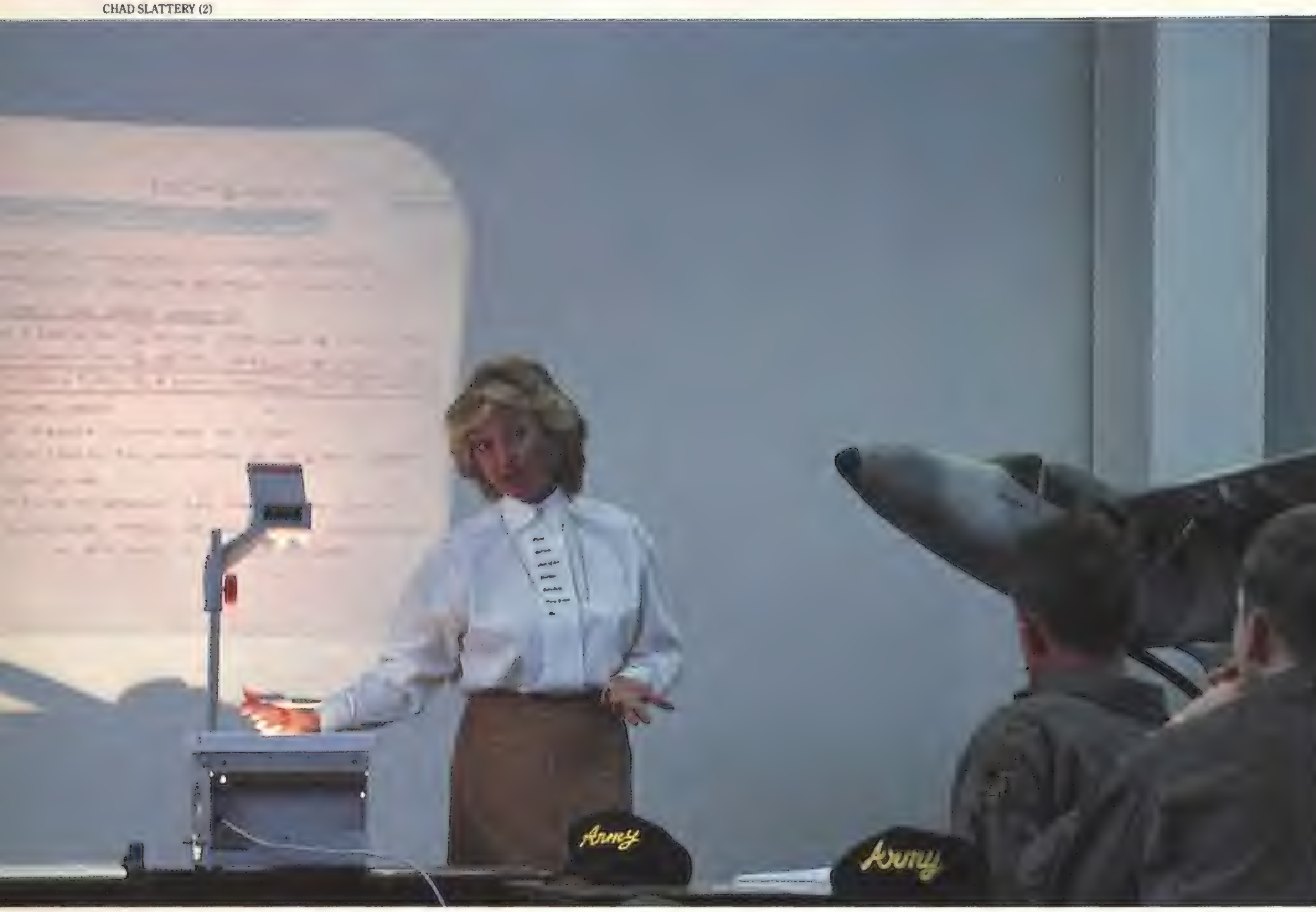
By 1986 Roberts had decided that the school was going to have to stay closer to its Mojave home, regardless of where the main demand was. Joe, the Thai squadron commander, was the first student to do the full 11-month program entirely in Mojave. He was followed by a pair of Indonesian pilots, the vanguard of a developing aerospace industry there. They will be the pilots and engineers on Indonesia's new AN-250 50-seat turboprop and, to a degree, the fathers of their own country's FARs. There have been students from Taiwan here on six month courses, a dozen from Italy's Aermacchi, a pair from Germany's Messerschmitt-Bölkow-Blohm, and five from the Spanish aircraft manufacturer CASA.

"When people go back from here they are scheduled to become test pilots, often in countries without a highly developed aircraft industry," says John Brown, who came to Mojave from the Royal Air Force, where he trained at the Empire Test Pilot School, the world's first, at Bascombe Downs. "Taiwan is building the AT-3 twin jet attack trainer and is about to build something like an F-16, and they will be test flying their own aircraft."

The cadre has grown to a dozen instructor pilots. Brown has since moved on to instruct at Northwest Airlines' flight simulator facility but returns to Mojave now and then as a guest lecturer. Nadia Roberts, Seán's wife, is also on the NTPS faculty. A native of Quebec, she met Seán while working as an engineer at Canada's Cold Lake test center. She is current in most of the school's equipment.

Real-world opportunities for testing have started to materialize. Students re-

CHAD SLATTERY (2)



cently finished gathering flight test data for a new airplane a company called Spectrum is building out of Cessna Skymasters. The Spectrum is "stretched" several feet longer than the Skymaster, with the nose engine removed and the rear engine replaced by a turboprop. For the airplane to be certified, someone has to fly it so that its handbook can be drafted and its behavior weighed against FARs. In exchange for the invaluable experience the task afforded its students, NTPS has provided flight test data the Spectrum will need in its quest for certification. Similar pre-certification projects are on the horizon.

In two experimental projects, students have also evaluated new inventions for manufacturers. One was a set of goggles for instrument flight instruction. Called Foggles, the glasses can be partially fogged, simulating flight in instrument conditions more realistically than the visor currently used by students. The other was a "force glove"—a standard Air Force flying glove that was modified to sense the amount of force being exerted on the controls, which is useful in testing an aircraft's handling qualities.

Instructor Nadia Roberts is a former Canadian Air Force flight test engineer and pilot.

Except for tours of duty in Korea and Vietnam, Wendy Shawler has almost always been a test pilot.

Last year the school wasn't able to accommodate all of its applicants. New classes have been offered, more instructors hired. But much of the work is still done on the road. This summer Roberts will once again fly a circuit that includes the Navy's postgraduate school in Monterey, California, Wright-Patterson Air Force Base in Ohio, the Navy test pilot school at Patuxent River, Maryland, and Cold Lake test center in Canada. By now it is an almost annual circuit, and Roberts flies either the Merlin or the Dove. It seems appropriate that the Dove, the airplane that Roberts holds in highest esteem, still makes the trip. For it is on the wings of this Dove—both figuratively and literally—that the test pilot and his school first took flight.

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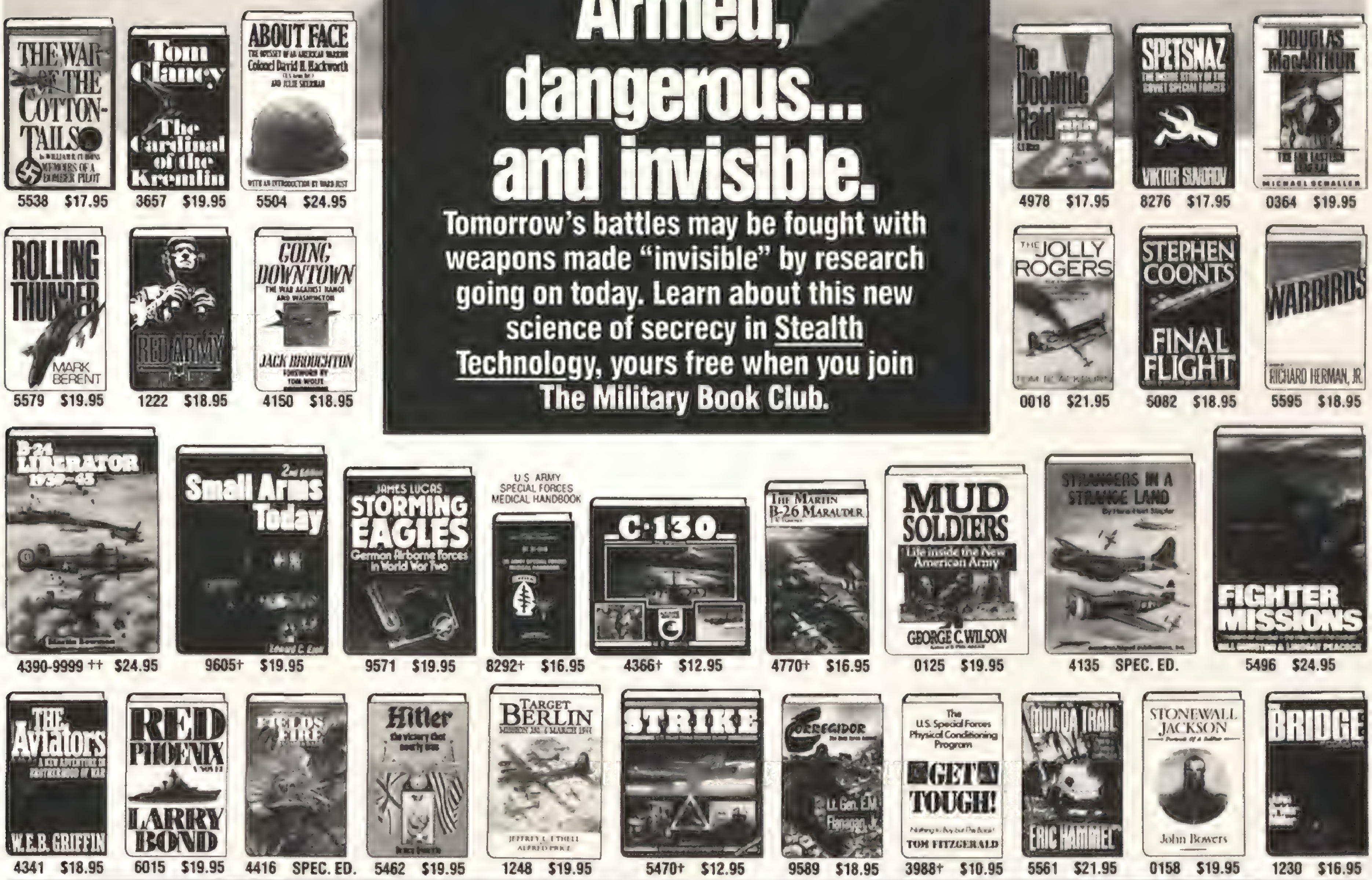

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A Permanent Presence: *Third in a Series*

Although the settlement of space is at least a decade away, NASA is making plans for the journey outward.

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Invasion of the Spacebots

NASA is looking for a few good machines.

by Greg Freiherr

It is Saturday afternoon at the Massachusetts Institute of Technology in Cambridge, and graduate students in the space systems laboratory are going through a biweekly ritual. They jam connectors into pockets, drape jumbled wires over computers and hustle them out to waiting cars, load pipes and metal cages onto pushcarts, then squeeze them into an elevator that eases them down to the loading dock.

This collection of parts—the frames and guts of two robots known as the Apparatus for Space Telerobotic Operations and the Multimode Proximity Operations Device—is being brought piece by piece to the alumni pool about half a mile from the lab. There ASTRO and MPOD will be assembled, submerged, tested, pulled out, broken down, and stored—all in two days. Usually there is a third robot—the Beam Assembly Teleoperator. But this week BAT is being overhauled, making the students' load a good bit lighter.

In full stride, carts clattering before them, the students head out the driveway behind the lab, into a heavily trafficked street, on to the sidewalks of a back road, through a gate, and up to a door that leads to the pool. Then the forward march of space robotics comes to a halt. The school water polo team is still practicing; ASTRO and MPOD must wait in the courtyard.

CHARLES H. PHILLIPS

Before NASA builds a robot, scientists use computer simulations to test its ability for space work.

The face of the future in space will likely have a metallic gleam, though it probably won't look quite as human as this fellow, a creation of advertising.

Although being developed under a NASA grant, ASTRO, MPOD, and BAT will never fly anywhere beyond a few humble swimming pools. Their successors, however, may one day fly in space, assisting astronauts in assembling space station Freedom.

The robots are part of a new army of laborers NASA is developing at labs, universities, and other institutions to work in space. These future workers are deemed important enough to be mandated by law: in 1984 Congress passed Public Law 98-371, requiring advanced automation and robotics to be "an integral part of the space station's planning and development."

The Goddard Space Flight Center in Greenbelt, Maryland, is the lead NASA center for developing the robots that will help assemble, fix, and service the station. Goddard is working on what will probably be the first practical space robot, the Flight Telerobotic Servicer (FTS). Another intended for space station work, the EVA (extravehicular activity) Retriever, is under development at the Johnson Space Center in Houston. Its job will be to fetch tools—or astronauts—tumbling away from the station.

Other robots intended for space work include several under construction at the Kennedy Space Center at Cape Canaveral, Florida. They will perform hazardous launch duties and inspect the 26,000-plus ceramic tiles on each shuttle when the orbiters return from space. Some—still in the planning stage—will even tend crops in orbiting hydroponic gardens. And in Huntsville, Alabama, scientists at the Marshall Space Flight Center are designing robots that will

JON BRENNEIS

Linked to a computer, the DataGlove allows the operator to "touch" computer-generated objects.

help perform experiments in orbit.

While "robot" is, loosely, the term for any automated machine, we tend to associate it with the humanoid beings that populate science fiction books and movies. NASA's spacebots fall far short of such complex machines, but they are nonetheless the fulfillment of dozens of science fiction visions. Space exploration has made them a necessity.

According to NASA projections, a shuttle crew can perform at most a total of 50 hours of work outside the spacecraft during a one-week mission. That includes the two days astronauts require for adaptation to space and assumes that there will be two astronauts outside the spacecraft (with one inside for support) working six hours per day on alternate days, with one day for cleanup. In contrast, robots could be operated at least 16 hours per day for perhaps six of the seven days in orbit.

Economics also increase the robots' appeal. The cost of keeping an astronaut in space ranges from $10,000 to $100,000 an hour, depending upon crew size and whether the astronaut is in or outside the spacecraft. Robots could do some of that work for a lot less.

Still, some pockets of concern remain. "There is a nervousness," says James Andary, systems manager of the FTS project at Goddard. "There is a

Gloves and helmet together let a user enter a computer-generated reality that is useful in robot control.

NASA/AMES RESEARCH CENTER (3)

real fear in trying something new, especially when it involves the success of the station." But he adds, "We're not going to fight to assemble it all ourselves. That's not our mission. We're going to be on station for 30 years. We'll have plenty of work to do."

The astronaut corps seems to agree with that assessment. Members are already working with robot prototypes and making suggestions for improvements. "It's always been put as a conflict—man versus machine—and I really don't think that's the case," says three-time space veteran George "Pinky" Nelson. "We'll be happy to see robots floating out there, as long as we can go up and work on them."

The astronauts aren't in danger of losing any glamorous jobs to their mechanical colleagues. NASA hopes the robots will take over the rotten jobs in space—the dangerous, the rigorous, and the boring. Machines excel at what people do worst. They can continuously monitor a situation and repeat precise tasks endlessly—or at least until their power runs down. They respond instantly to signals, ignore distractions, and compute huge quantities of detailed data in a short time. With the right "hands," robots can reach into places too small for an astronaut wearing a bulky spacesuit. They can also handle hazardous substances such as fuel.

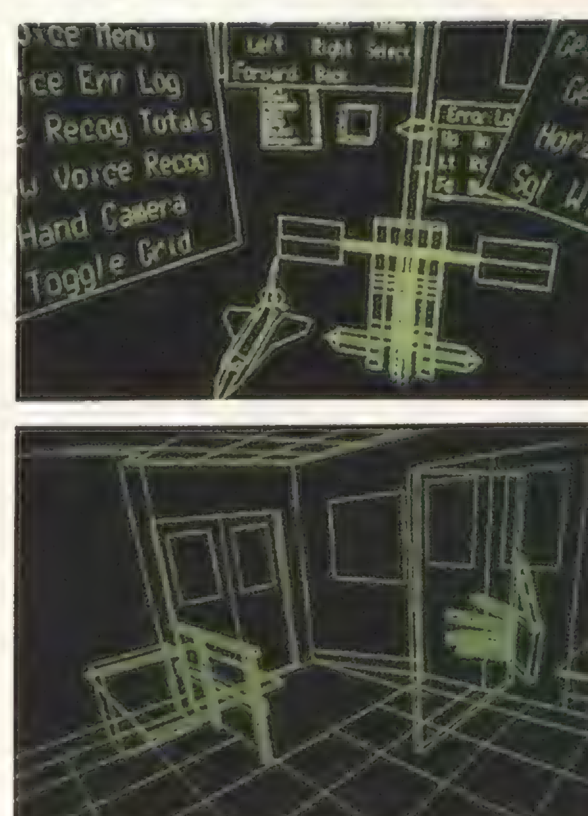
Giving robots the repetitive and boring tasks in space might in itself reduce the potential for injury to astronauts. "The chance of making errors and mistakes increases the more that a single task is performed," explains Giulio Varsi, director of the robotics program at NASA's Jet Propulsion Laboratory in Pasadena, California. "After a hundred or a thousand times, that task might become unbearable. And the likelihood of a bad occurrence increases."

Simple and repetitive tasks may, for the time being, have to form the bulk of the robots' work anyway. While science fiction robots have been capable of independent thought, emotions, even a little cooking and sewing, scientists are finding that endowing a mechanical being with even the most basic human functions is a monumental challenge.

At Carnegie-Mellon University in Pittsburgh, a single robot leg hangs from the ceiling of a building the size of an aircraft hangar. The leg is part of The Ambler, a six-legged, 15-foot-tall planetary walker being developed here in conjunction with JPL.

The Ambler was inspired by the experiences of project director William "Red" Whittaker—not in an engineering lab but on the sides of mountains. A mountaineer who has climbed dozens of summits, Whittaker thought about the way he approached obstacles—his use of rigid boots and axes to scale vertical sheets of ice and the technique of jamming his hands into the cracks of smooth sheer rock—and started to see the advantages of arms and legs for robots sent to explore other worlds. "As a climber you make your way by planning, stepping, and gripping," Whittaker says. "Those insights provide significant advantages when addressing the

Images projected into the helmet give the operator access to computer menus (below) by speaking or gesturing, or the ability to enter a room and "touch" its walls (bottom).



challenge of where machines might go in space."

On Mars a walker would have an advantage over wheeled vehicles on soft or rugged ground, where the resistance to movement increases drastically. Whereas the wheel must push through or around what is in front of it, a foot simply lifts up and away. Boulders can be stepped over. Instruments aboard would ride smoothly, not swaying as they would on a wheeled vehicle.

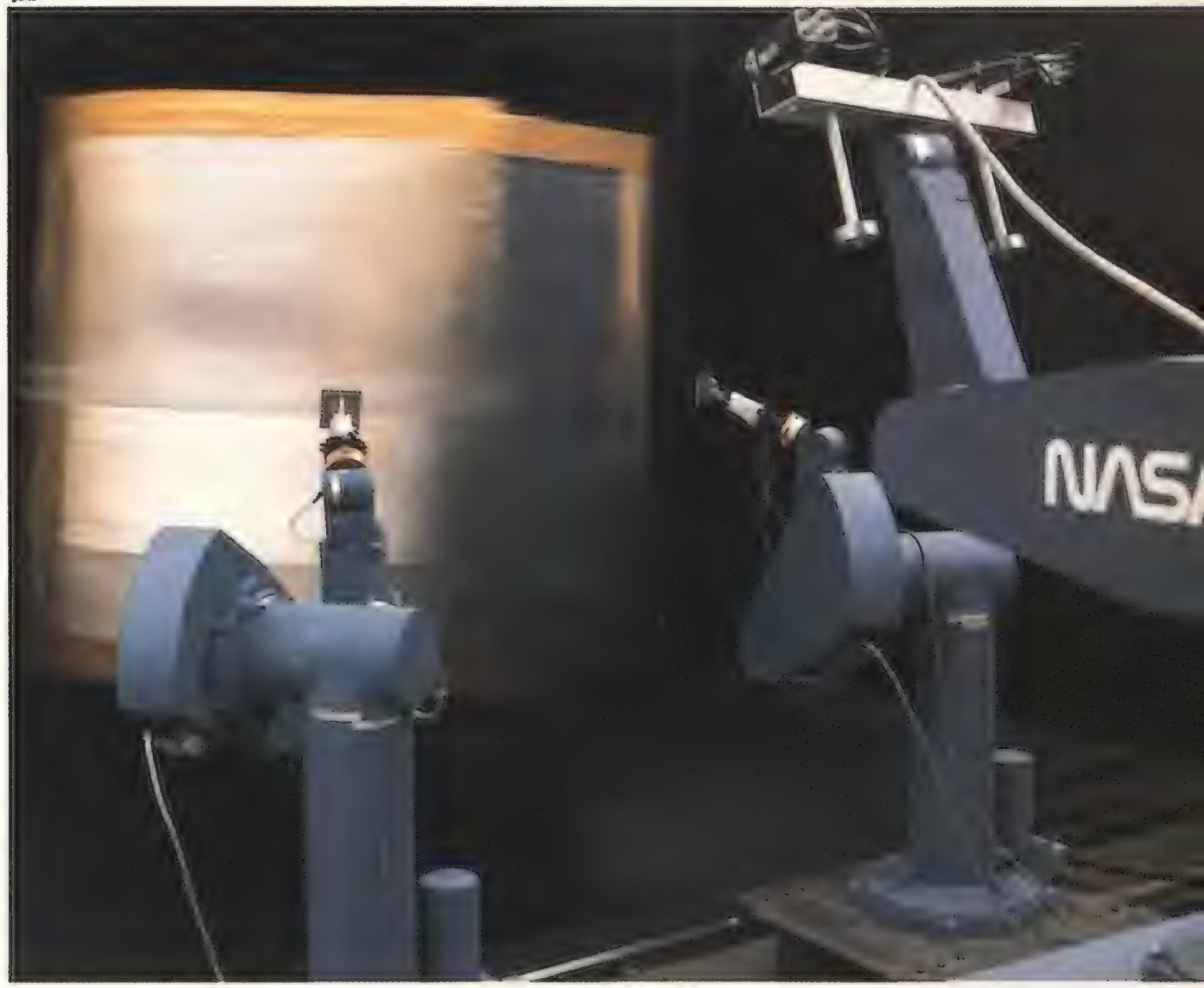
But, as the scientists are discovering, a small step for man is a giant leap for robots. Each footstep in the huge sandbox that serves as the leg's testing ground has to be precisely planned, the choice of a robot brain that first laser-scans the surface, picks the flattest spot, swings the top and middle joints of the leg forward, and lands it. With each step of the leg, a tractor containing a computer and laser scanner rumbles forward along a steel rail that runs the length of the ceiling. "It somewhat resembles a cross-country skier," says Kevin Dowling, Carnegie senior engineer on the project. "The leg moves, the leg plants, and then it slides the trolley forward."

At Goddard's robotics testbed, scientists are grappling with the intricacies and occasional hazards of developing powerful robot arms. At the far end of the lab, roped off and plastered with DANGER signs, is a two-armed robot that towers eight feet tall, its silver arms flexed, its hands poised. The robot has a 50-pound lifting capability, explains David Provost, head of Goddard's robot data systems and integration section. "That means it can move 50 pounds accurately to within a thousandth of an inch. But it is capable of moving hundreds of pounds not very accurately through a wall."

Provost recalls a time when a robot arm with that power was programmed to open a door set up in the lab. The night before an important demonstration, a technician adjusted the software to accommodate a slightly smaller replacement door that had just been installed. The next day, the demo went well "up until when the robot ripped the door off," Provost says, laughing. "Robots are extremely strong, and if you tell one that a door should go further than it can, it won't stop until the door gets there."

Red Whittaker (center, with glasses) and students cluster around the Ambler's lanky leg.

JPL



At JPL, robots with rudimentary vision systems are programmed to recognize a satellite and "de-spin" it.

Tests at JPL have determined that it's possible to crudely approximate human senses in robots. In a well-lighted and highly controlled environment, one robot was taught to recognize the outline of a satellite mockup, grab the sides, and "de-spin" it before the mockup could get out of reach. The robot performed well many times, but on the day officials from NASA headquarters came to visit the robot was anything but cooperative. A postmortem revealed that because the background lighting was not quite right, the vision system failed to lock on to the target. "It didn't do anything," Varsi says. "The mockup went by and the arms just stayed there."

Similar problems have befallen Ricky and Fred, two industrial robot arms at the Goddard lab named for the characters on the "I Love Lucy" show. They work on mockups of space station components that an overhead gantry robot brings them. Ricky and Fred extend legs attached to the components and lock them down. But to accomplish this simple task a vision system has to recognize the target, a ranging system has to measure the distance to it, and a computer has to plot the course to a "grapple fixture."

During one test, Ricky extended his arm toward a module leg, then suddenly stopped dead. The lighting was wrong and Ricky's vision system could not see the target well enough to make out the positioning dots used to align the robot's hand. Sometime between the period when the operator programmed Ricky that morning and the beginning of the test, somebody in the lab had turned off an overhead light. That was all it took.

One way of circumventing such mishaps is to combine the brute strength and durability of robots with the intellect and perceptual abilities of humans.

NASA

Such robots are known as "telerobots." The extension of reality its operator experiences is known as "telepresence" —literally the next best thing to being there.

The Flight Telerobotic Servicer is such a creature. In development at Goddard in conjunction with several other NASA centers and being designed and built by Martin Marietta Aerospace, the six-foot-tall FTS is one of the most human-looking robots now on the drawing boards. Two cameras with zoom lenses and spotlights will be mounted on its head. There will be one arm at each side. Cameras attached to the wrists will provide close-up views of what the hands are doing. A third arm attached to the bottom will hold the robot in place.

An astronaut, operating the FTS from the relative safety of the shuttle or space station, would direct the robot's arm movements by moving his own arms, and, by virtue of the robot's camera eyes, would see the action as the robot is "seeing" it, giving him the sensation of being outside the ship, at one with the robot.

The latest addition to the Goddard lab is a small master controller that will heighten the effect by allowing the FTS's astronaut operator to feel some of his mechanical counterpart's effort. Developed at JPL, the controller transmits physical sensations from robot to operator. As a robot carries out a mechanical task, the operator feels resistance transmitted back to his hand at the controller through sensors built into the robot arm. The operator may then know to bear down on the controller to get a board plugged in or twist harder for the robot to tighten a bolt.

A prototype of the FTS is scheduled for a September 1991 ride into space, where it will be tested in the shuttle bay.

While delicate work such as the repair of the Solar Max satellite (at center, above) may remain a human task, much future space construction will likely rest in the able hands of the FTS (right) and other robots, under astronauts' direction.

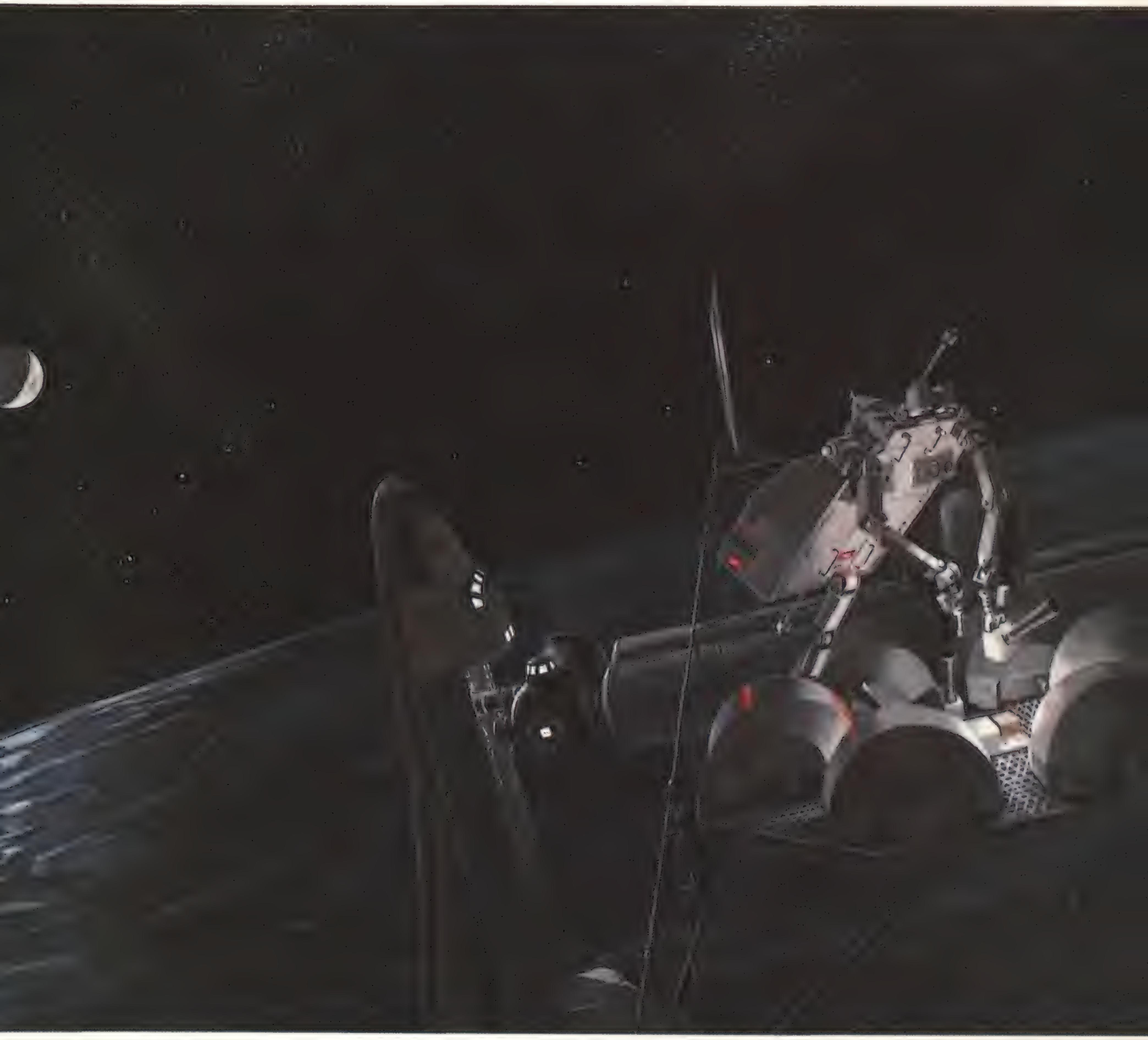
MARTIN MARIETTA

A full demonstration is scheduled for two years later. In the meantime, scientists at Goddard are using computer simulations to work out details of some of the robot's capabilities and its techniques for "collision avoidance."

"Almost every mechanical component that you use in a robot or mockup has potential problems in not having enough reach or in hitting another component," says Lloyd Purves, deputy director of Goddard's office of telerobotic engineering. "And so the computer simulation work is done to make sure that we have the needed clearances and reaches."

On the computer screen, the FTS appears at the end of the shuttle arm. The Goddard robotics technician switches to a view from the robot's hand. The screen rotates and moves in on a space station payload. The hand inches its way along, zeroing in closer and closer. The hand turns yellow, a warning that it's off the mark and must be moved. Then it turns red. "Oops," the technician says. "That happens." In computer simulations, as in space, no one can hear you bang the hardware.

Other extensions of telepresence include a helmet in which three-dimensional images are projected and a glove that records the movements of the



hands. Both systems were developed by VPL Research Inc., a small Redwood City, California company, and are already in use at NASA's Ames Research Center in Mountain View, California. "Our goal is to make the connection between person and computer—to make it transparent," says Ann Lasko-Harvill, VPL director of product design.

VPL's DataSuit (which covers the entire body) and DataGlove are garments striped with fiber-optic cables. When the wearer is standing upright and perfectly straight, the light flow is unimpaired. But bend an elbow, a knee, a hip, a finger, or a wrist and sensors record the shift in beam patterns. Data is processed and the computer model of the person assumes the new position.

Link the data to a three-dimensional rendering of a place—a building, a spacecraft, another planet—and the computer-generated image of the person wearing the garment can interact with the environment. A stereo display in the helmet provides the view.

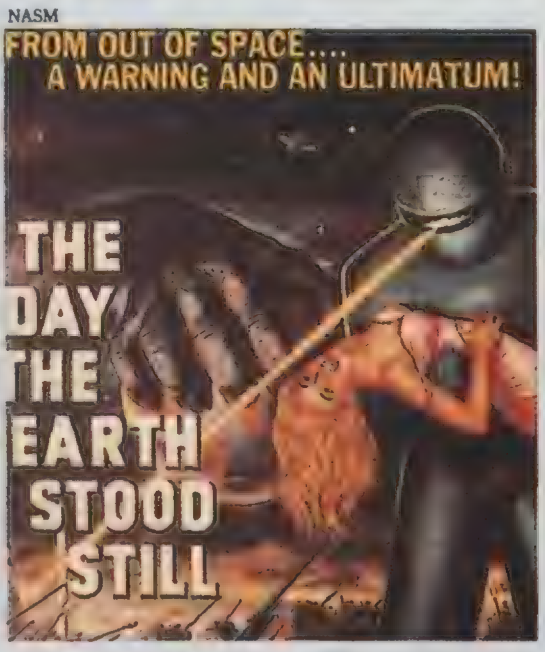
"Everything I see is as it would be if I were there," Lasko-Harvill says. "When I manipulate something, it is as though I am really manipulating it. If I twist something, I see it turn. If I invert something, I see the other side of it. Whatever I do, I have that kind of continual sense of it being real."

Studies at Ames are directed at developing the techniques needed for an astronaut inside the shuttle or space station to control a robot floating outside. Wearing a helmet equipped with "eye phones," an astronaut could pan the work area, directing the cameras mounted on the robot by moving his own head. He could move the robot arms and hands by moving his own, and see what the robot sees on the 3-D display in the helmet (see "The Big Picture," April/May 1987).

At MIT, the robot researchers are long on spirit and short on cash. Making do with what they can afford, they have modified a Sega video game to provide stereo vision from images captured with television cameras mounted on MPOD. The cost is $150 for the Sega machine versus $30,000 for a vision system like the one the satellite-grappling robots use at JPL.

It is Sunday, the morning after a night of preparation and system checks.

NASM



20TH CENTURY FOX

NASM

If the word "robots" excites the mind with images of wise mechanical companions, it's largely because of the machines who rolled, bleeped, and blinked their way through science fiction films. Perhaps the most famous sci-fi robot of all, Robbie of Forbidden Planet *(1956; above), could sew dresses, speak dozens of languages, and brew whiskey. The personable Robot of the mid-1960s television series "Lost in Space" (left, bottom) was originally intended to be destructive, but reprogramming brought out his amiable side. Mute and more menacing, Gort from* The Day the Earth Stood Still *(1951) became a machine of action after being told the enigmatic words "Klaatu barrada nicto."*

NASA/MARSHALL SPACE FLIGHT CENTER

David Akin and his sidekick, BAT, simulate a space repair mission in a Marshall Space Flight Center tank.

Scuba divers break the flat surface of the water, sending points of light dancing across the pool. MPOD is lowered gingerly into the water, and the divers cushion the robot as it settles to the tiled floor, unhook it from its hoist, then begin flipping the switches that will bring it to life.

The divers give the "go" sign. The operator—her back to the pool, eyes fixed on the television screen and the cross hairs that represent the robot's docking probe—summons her craft. Propellers, the water equivalent of space thrusters, whirr to life. MPOD lifts off the bottom and bobs toward a target strapped to the pool wall.

Forward a bit. Then back. Forward a bit more. Up. Each tap at the controls sends MPOD in one direction or another. The orange marks on the screen are the target; the black ones show the position of MPOD's docking probe.

"Keep in mind that besides trying to do good research, which of course we always want to do, we're trying to give the kids some education, and I don't think there's any better way to do it than hands-on," says David Akin, associate director of the space systems lab.

Each year, in the dead of winter, Akin and his group pack up their three robots and head south to the "neutral buoyancy simulator" tank at the Marshall Space Flight Center. A year ago Akin played astronaut there with BAT at his side, working on a mockup of the Hubble Space Telescope.

The robot was handing him tools; Akin was handing them back. Suddenly the wrist just rotated out of its socket and sank—hand and all. "It's not the kind of thing you want to talk about on the [communications] loop, so I said to one of the grad students, 'I think maybe we are out of battery power,' " Akin recalls. "She replied that we have plenty. I said, 'No, I think we are out.' "

The student caught on. The test ended. The support divers grabbed the robot—and its hand—and Akin and the students left. For that moment, the helping hands would have to be human ones.


USA

Venus on a Shoestring

Money is tight, but the scientists at Project Magellan are proving that less can be more.

by Don Wilhelms

Among the forms 1960s nostalgia has taken is a longing for the days when time, not money, seemed to dictate the course of the space program. Americans were determined to ride Apollo to the moon before the end of the decade, no matter what the cost. As one of those who helped plan and analyze the data return from Apollo and its unmanned precursors, I had the luxury of worrying more about squeezing out the data we needed in order to understand the moon's surface than about where the next dollar was coming from.

Plans for the future were even grander. Elaborate lunar expeditions and permanent Earth-orbiting space stations, developed under an Apollo Applications Program, were to follow the early moon landings. The magnificent Saturn Vs that sent the astronauts to the moon could send massive robot spacecraft to Mars by the early 1970s. Other spacecraft would take advantage of a once-in-a-lifetime planetary alignment to conduct a "Grand Tour" of all five outer planets, including Pluto. Space shuttles, each reusable up to a hundred times, would take off almost every week to do almost everything the other rockets in NASA's stable could do, but more cheaply. Americans would land on Mars by the end of the century—possibly as early as the 1980s.

What actually happened was a complicated mix of sunny dreams and gloomy reality. By 1970 funding had replaced time as the item in short supply. Production was stopped on the Saturn V, three Apollo landings were canceled, the Apollo Applications space station—Skylab—went unoccupied for more than five years before burning up in Earth's atmosphere, and the space shuttle was scaled back and compromised with results that would become painfully obvious.

But the community of planetary scientists and engineers was not ready to give up its dreams. A spacecraft named Magellan, currently en route to Venus, beautifully illustrates the kind of adaptations to fiscal reality that were made.

These new limitations first made themselves felt before the mission of Mariner 10 to Mercury. A direct trip to Mercury would require a rocket that was more powerful and more expensive than the one the experimenters had available. Fortunately they proved brain power could equal rocket power: Mariner 10 got the boost it needed from Venus' gravity in a slingshot trajectory that between March 1974 and March 1975 had it fly by Mercury not once but three times.

The proposed Mars probe likewise had to do without the powerful Saturn V; it became instead the somewhat more austere Viking and did not land on Mars until 1976. Since then, however, the two Viking landers and orbiters have wrested one secret after another from Earth's next outward neighbor. And although Pluto will probably not be visited by a spacecraft for many decades, one could hardly wish for a more spectacular gallery of images from a Grand Tour than the one recently rounded out when Voyager 2 passed Neptune and its moon Triton twelve years after leaving Earth (see "Goodbye, Voyager," December 1989/January 1990).

In 1970 NASA's Jet Propulsion Laboratory set up a group to look into a Venus radar mission. Hidden by a dense, murky atmosphere, the planet is somewhat secretive. Any images of Venus' surface would have to come from landed capsules, which provide a very limited view, or from radar.

Earth-based radar is limited by its great distance from the target and its inability to make images of more than a fraction of the planet. To get a better view, radar instruments would have to be placed in orbit around Venus. But with conventional radar the degree of resolution is tied to the size of the antenna's aperture: the bigger the better. And there was no chance of building a monstrous Venus-bound spacecraft that could carry a radar dish hundreds of yards wide. The solution, then, was to use a radar technique that imitates the effect of a large aperture—something known as synthetic aperture radar (see illustration, next page).

JPL's study of options for its radar orbiter took as its base NASA's ocean-scanning SEASAT spacecraft, which in 1978 used synthetic aperture radar from a circular orbit so successfully that it showed things in the world's oceans that the Navy neither expected nor wanted to have shown.

The spacecraft that was proposed was VOIR, standing both for the French verb "to see" and for "Venus Orbiting Imaging Radar." VOIR would be braked into a circular orbit by a combination of powerful liquid-fuel rockets and the effects of aerobraking—plowing precisely through the upper Venusian atmosphere. Its radar would penetrate the Venusian clouds, revealing targeted features as small as 250 feet across. Five other instruments would examine Venus' lower atmosphere and ionosphere.

NASA announced VOIR as a new project for the fiscal year beginning in October 1981. But the startup came to an abrupt stop three months later, when budget restrictions forced the project's cancellation.

Magellan, a tightly budgeted hodgepodge of spare parts, sets off on its 15-month journey to Venus.

NASA

The death of VOIR was not the end of American designs on Venus, however. VOIR engineers and scientists, unwilling to abandon what could be—second only to Earth—the most interesting planet in the solar system, went back to the proverbial and actual drawing boards. After a few intense months of complex and, I think, brilliant trade-offs, a very different mission emerged.

The circular orbits planned for VOIR were replaced with elliptical orbits, which wouldn't necessitate a powerful, heavy propulsion system and aerobraking maneuvers. VOIR's unprecedented data return, four megabits per second, was sacrificed for a more modest rate. The elliptical orbit permitted a longer period during which the spacecraft's antenna would have a view of Earth. Costly additions to the system of Earth-based antennas called the Deep Space Network and the development of a high-rate radio link could be avoided. The problem of designing and constructing the five atmosphere instruments planned for VOIR and expected to cost about $70 million could be solved even more simply: they were dropped entirely.

The project would also save money and time by shopping around for spare parts. The Voyager project happened to have an extra 12-foot high-gain antenna. It was not really the right shape for synthetic aperture radar but would do in a pinch. It could also be pressed into the very different duty of communicating with Earth. In addition, Voyager and

TASS FROM SOVFOTO

Magellan's synthetic aperture radar will achieve the results of a far larger fixed aperture—or conventional—radar by acquiring radar reflections along long stretches of an orbit and synthesizing them into images by computer. For about 37 minutes of each three-hour, nine-minute orbit around Venus, Magellan's SAR will bounce pulses off 16-mile-wide swaths of the planet's surface. During much of the remainder of each orbit, the spacecraft will then turn its antenna toward Earth and radio its data to the antennas of NASA's Deep Space Network.

other projects could provide some components of the propulsion, radio, and thermal control systems and even the spacecraft bus, which houses such basic items as flight computers and data recorders. The computers themselves—more powerful than those intended for VOIR—came from the Galileo mission to Jupiter. Only about a third of the new spacecraft would have to be specially built.

NASA, suitably impressed, allowed preliminary studies to continue and announced the mission as a new start as of October 1983. The JPL project scientists and engineers and the experimenter team moved intact from VOIR to the new project, named Magellan in 1986 after the leader of the first seafaring expedition to circumnavigate the globe.

The Soviet Venera 13 photographed Venus' surface in 1982; Magellan will bestow a much broader view.

Magellan's shoestring operation may actually have resulted in a better mission than VOIR for investigating the surface of Venus. Its image resolution will probably be better, a tenfold improvement over images of Venus taken by the Soviet Venera probes and by Earth-based radar. It could potentially match the 300- to 400-foot resolutions routinely obtained in 1967 by Lunar Orbiter 4's survey of the moon's near side, on which I spent many years of my career; Magellan, however, would map areas 25 times larger. The relation between data and funds appeared to be the reverse of the one I knew in the 1960s: data would flood in even though dollars from the congressional pipeline only trickled out.

Budgetary problems were not Magellan's only obstacle, however. The first planetary probe to be launched by shuttle, Magellan was originally scheduled for launch in April 1988, one of the opportunities that open up every 584 days in which Earth and Venus are aligned in a way that allows a direct, three-month-long flight. Then, in January 1986, *Challenger* blew up and the world learned how unwise NASA had been to depend only on its shuttles.

Magellan was rescheduled for the launch window that opened on April 28, 1989. This was not one of the windows for a direct trajectory to Venus, however; Magellan would have to take a longer trip, looping one and half times around the sun before finally encountering the planet 15 months after launch. The scenario was not ideal, but the next launch window for a direct flight, opening last October 12, was desperately needed by the even longer-delayed Jupiter probe Galileo, which had originally been scheduled for launch in 1982.

Magellan's shoestring budget was acquiring a gold plating. The delays have already cost the project about $200 million of the money saved by scaling down VOIR, or about 40 percent of the project's anticipated budget. Delays have cost Galileo far more.

After a few more postponements and scares, the shuttle *Atlantis* finally got off the ground on May 4, 1989, carrying the flying garage sale called Magellan. Even those of us not connected with the project were entitled to a great sigh of relief later in the day when the spacecraft and its inertial upper-stage booster were pushed out of the shuttle's bay and fired off on Magellan's intended path to Venus. The first of three mid-course corrections, changing the spacecraft's velocity by only five feet per second, also went off without a hitch on May 21. The next would not come until this March, and it won't be until August that Magellan is injected into orbit around Venus.

To outsiders, it may seem as if Magellan is now living according to the laws of celestial mechanics, and that the project managers, engineers, and scientists have nothing to do but wait for the next mid-course corrections and the orbital injection. It is true that engineer John Gerpheide, who had ably led the project since the VOIR days in 1981, retired last September after the bird left the nest. It is also true that the excitement and tension that built up before the launch have subsided somewhat. But in fact, all the people connected with the project are just as busy as they were before May 4.

The software for operating the radar is still being developed by the Hughes Aircraft Company in El Segundo, California, the contractor for the radar system. The change from a circular orbit to an elliptical one has made the job much more complex, but the work is expected to be completed and tested on time—about three to four months before Magellan reaches Venus. And the elaborate commands that will be sent up to the spacecraft during the mission are being tested with a complete computer mockup at the Denver plant of the spacecraft's builder, Martin Marietta.

The spacecraft is being carefully monitored during the cruise. Gerpheide

and mission director/deputy project manager Tony Spear (who has since taken over Gerpheide's role as project manager) describe the preparation for orbital insertion as being just as demanding as preparation for the launch; members of the attitude control team and the subsystem specialists on the spacecraft team still come in at all hours of the day and night.

The 28 scientists of the radar team are using the interval to fine-tune their plans for formatting, processing, and handling the firehose stream of data they expect. The Project Science Group, a subgroup of the experimenter team, meets quarterly as it has since October 1982. The experimenters seem determined to leave no stone unturned. At a meeting I attended last summer, action items from the previous meeting were acted upon and decisions made or firmed up. Anna Tavormina, one of the mission planners (and since promoted to chief of the mission planning team), described how her group had figured out a way to reduce the area lost to mapping when Venus comes between the spacecraft and Earth and prevents the playback of some mapping

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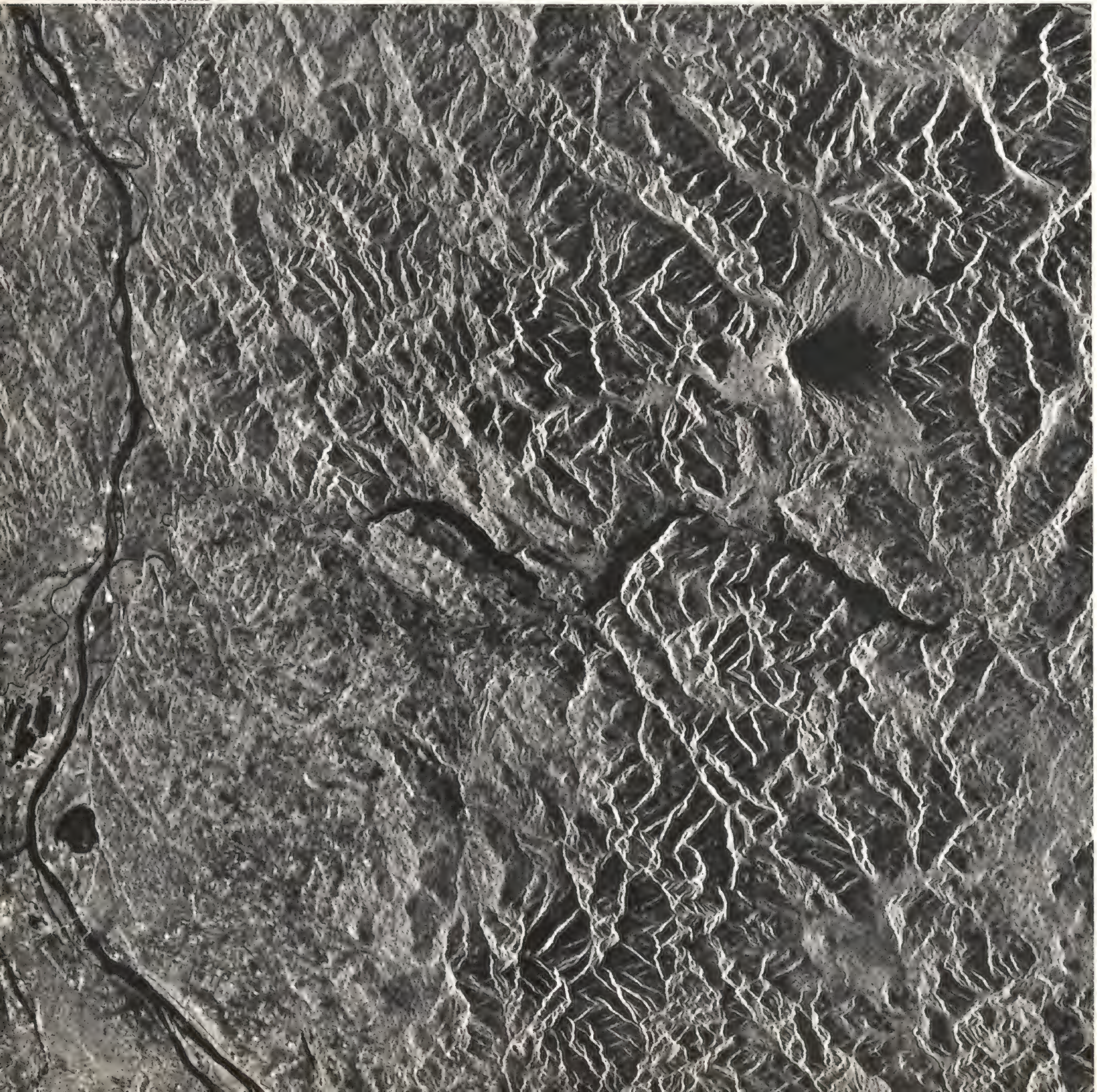
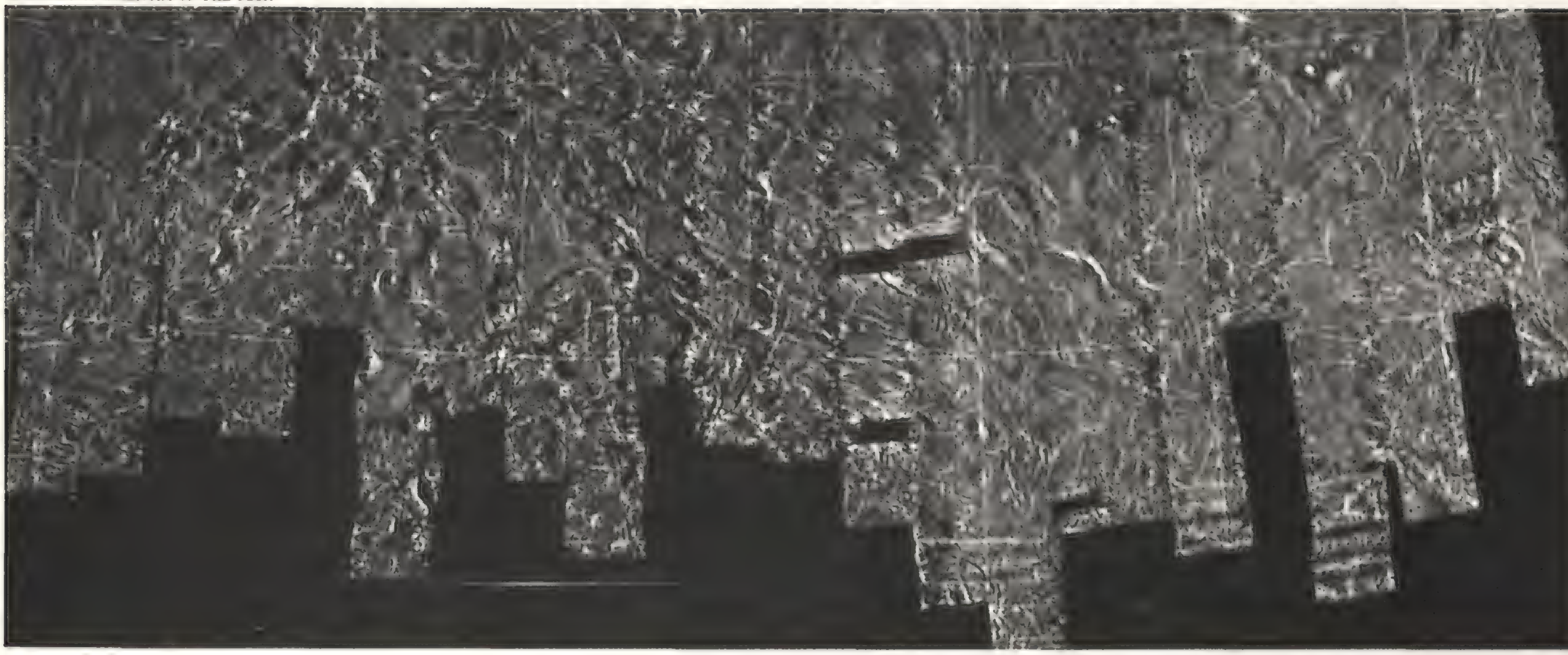


ACADEMY OF SCIENCES OF THE USSR



Magellan's images will provide a tenfold improvement in resolution over those from Venera 14 and 15 in 1983.

A SEASAT image of Mt. Saint Helens shows the capabilities of Magellan's similar SAR (left).

data. (Their solution: adjust the locations of data collection over each swath of Venus to reduce the data redundancy from one orbit to the next.)

Another discussion concerned Magellan's "extended mission." In the 1960s only nominal missions were planned and everything extra was gravy. The nominal mission for Magellan is one Venus day, which equals 243 Earth days. Most American unmanned missions since the mid-1960s have lasted longer than expected, so from the beginning, the project team has hoped that Magellan's mission will be extended. If all goes well, the extended mission will continue through several 243-day cycles.

Most of Gerpheide's presentation at that meeting was full of optimism—the launch had been smoother than the simulations, the deployment of the upper stage had been flawless, and the mid-course correction had been smaller than had been thought necessary. Then came a conspicuous "however."

The workload for the software teams at Martin Marietta and Hughes was turning out to be greater than anticipated, and some of that work may have to be trimmed for lack of funds. It would get done somehow, but other work would have to be deferred. Tony Spear called this the bow-wave effect—the immediate budgetary problem may no longer be a pressing issue, but only because it has been pushed ahead. Magellan's scientists worry that if the bow wave persists, there will not be enough funding left to analyze the data as it is received in order to report the preliminary results to the public (see "NASA's Data Deluge," October/November 1989).

The volume of imaging data will be enormous: more than that from all other U.S. planetary probes combined. While orbiting between 155 and 1,300 miles over Venus' surface, Magellan will transmit microwave signals in carefully programmed bursts. After each burst the high-gain antenna will wait for their reflection from the surface and the tape recorder will store the data. At a certain point in the spacecraft's near-polar orbit, the antenna will turn to Earth and dump the recorded data onto one of the Deep Space Network's three large antennas at rates of up to 268,800 bits per second. Although this rate is not as fast as that originally planned for VOIR, Magellan will still transmit much faster than the last U.S. craft to orbit Venus—Pioneer/Venus 1, which, starting in 1978, has transmitted 1,200 bits per second.

The eventual result will be images of the entire planet except for the area around the south pole. A U.S. Geological Survey cartographic group will construct 62 maps at the scale of one five-millionth actual size and airbrush a map of all of Venus at the scale of one to 50 million, thereby summarizing details and rendering the overall appearance of the surface.

Scientists should then be able to learn how much Venus has in common with Earth—and how and why the planets differ. Because Magellan's radar will provide a dense network of elevation measurements accurate to 100 feet, the maps of Venus will contain far better data on heights and depths than is available for any other non-Earth planet. Only narrow strips of the moon overflown in 1971 and 1972 by the last three Apollo command modules will have been better mapped.

The gravity field of Venus will also be better understood than that of any other planet. During the Lunar Orbiter missions in 1967, Paul Mueller and Bill Sjogren of JPL discovered that small perturbations of a spacecraft's orbit can reveal details about a planet's gravity field. Sjogren is now one of the principal investigators of Magellan's gravity research group.

A geophysics working group will try to determine such things as the distribution and thickness of different kinds of rock beneath Venus' plains, plateaus, and mountains, and what is holding up its giant continent-size uplands.

Finally, a post-VOIR technological development independent of the Magellan project and JPL should help to get this data quickly into the hands of scientists. The images and altimetry data will be imprinted on CD-ROMs—compact disks for computers—and distributed to the experimenters and data centers at low cost, allowing researchers to hold in one hand the secrets of a planet the size of our own—and via comparative planetology, perhaps some of Earth's secrets as well.

LARTIGUE

At the turn of the century, early aviators owed much to bicycle technology (above). The relationship

by Chester Kyle and Wolfgang Gronen

ILLUSTRATIONS BY WEB BRYANT

In 1896 an 18-year-old bicycle racer named Glenn Curtiss won a five-mile race over the roads around Hammondsport, New York. He beat his competition so soundly, it was reported, that by the time the other racers finished, he was home eating dinner.

Curtiss went on to chalk up some notable firsts. One of the most significant, perhaps, was the first pilot's license in the United States. Another cycling enthusiast, Orville Wright, received license number two.

It's no coincidence that two of early aviation's leading figures were involved with bicycles. They were just the most prominent of the many aviators who entered the new field as bicycle merchants, designers, manufacturers, or racers. The restless, competitive spirit that made for a good bicycle racer also made for a good pilot. In fact, in the years before 1914 more than a hundred champion cycle racers worldwide became aviators.

At the turn of the century, transportation was in the midst of a revolution. In less than 20 years the nearly simultaneous development of bicycles, motorcycles, automobiles, and airplanes had

was especially clear in Aviettes, *wing-equipped bicycles briefly popular in France (right).*

NASM

The Bicycle-Airplane Connection

Many early aviators learned how to pedal before they learned how to fly.

moved the world from the horse and buggy age into the age of flight. The bicycle itself had recently undergone its own revolution. Before 1885 the most common versions were the high bicycles, upon which the rider perched, high above the ground, over a huge front wheel. Never particularly safe, the high bicycle was phased out after 1885 by the "safety," which had two wheels of equal size and was easier and safer to ride. The introduction of the safety bicycle made bike riding an international craze. Within a few years millions of bicycles were cruising the roads of Europe and America, and the bicycle had become the first means of individual rapid transit available to all. During its heyday the bicycle was considered high-technology transport, and great efforts were made to improve it. Its enthusiasts sought better frames, tires, wheels, and construction materials.

At the same time, aviation pioneer Otto Lilienthal was conducting gliding experiments in Germany that would have formidable impact on two Dayton, Ohio bicyclists. It was Orville, the younger of the two Wright brothers, who had first become interested in bicycles. After deciding to try his hand at racing in 1892, he put up $160 for a racing bike. Wilbur followed suit a few weeks later. By the end of the year the Wrights had decided to go into business repairing and selling bicycles; in 1895 the Wright Cycle Company began manufacturing its own line of bikes.

Though the Wrights succeeded, the bike business tended to slack off in the winter months, which meant the brothers had time to devote to a project that had captured their fancy: building a flying machine. Before they built their first wind tunnel, they had used one of their

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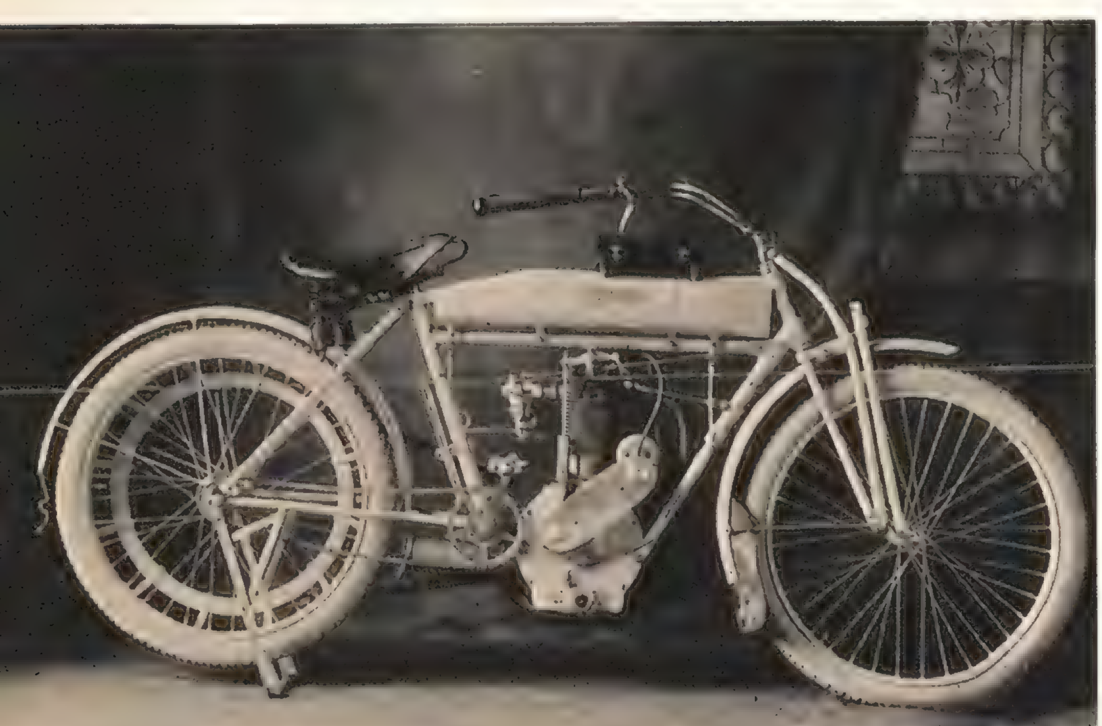


bicycles to test airfoils. They mounted a tire horizontally over the handlebars of one of their St. Clair models. On one side of the wheel they attached a flat plate; on the other, an airfoil. While pedalling into the wind a rider could adjust the airfoil to match the forces on the flat plate and get a rough idea of the lift generated. Using this crude device, the Wrights were able to prove that aerodynamic tables calculated by Lilienthal were incorrect.

Meanwhile, Glenn Curtiss was making a name for himself as a bicycle racer. A handsome but unsmiling man who never continued school past the eighth grade, Curtiss was a mechanical genius with a gift for recognizing business opportunity. He also had a penchant for speed and a strong daredevil streak that were perfectly suited to a racer—or an aviator.

He made the move from bikes to airplanes via the motorcycle. In 1901, Curtiss, then the owner of two bike shops, ordered some rough, unfinished engine castings and transformed them into a working engine, in part by fabricating a carburetor from a tomato can and some gauze screen. He mounted the 180-pound, single-cylinder gasoline engine onto one of his bicycles and named the contraption "the Happy Hooligan," after a comic strip character of the day. After a few false starts, he managed to get the engine going long enough to make a quick trip down the main street of Hammondsport.

Curtiss' second motorcycle, although an impractical, brakeless, belt-driven monster, was even better. But it was his third attempt, equipped with a lighter, more powerful engine, that would decide the course of his life. Curtiss sold this machine and suddenly he was in the motorcycle business. In 1903 he made a two-cylinder motorcycle engine and used it to win races and to set a world speed record of 63.8 mph.

Glenn Curtiss is the prototypical bicyclist-turned-aviator. But first he turned to motorcycles, manufacturing primitive, single-cylinder vehicles (bottom left). His motorcycle engines gained him entrée to the world of dirigibles, and he made his first flight in 1907 (top). Those same engines brought him to the attention of Alexander Graham Bell and the Aerial Experiment Association. Before long, Curtiss' achievements with airplanes rivalled those of the Wrights (bottom right).

Curtiss' lightweight engines were exactly what early aircraft experimenters needed. In 1904 circus performer "Captain" Thomas Baldwin used a Curtiss engine to power the first successful dirigible in the United States. Curtiss later built a light and more powerful engine in 1906 for the first dirigible purchased by the U.S. Army.

But Curtiss hadn't abandoned the world of wheels. Fueled by his passion for speed, he decided to mount a hulking eight-cylinder engine on a bicycle frame and create his most powerful motorcycle yet. Photos of the machine show a stretched, overgrown bicycle without suspension or proper brakes. It took real nerve to ride the contraption at any speed: in 1907 Curtiss astounded the world by reaching 136.3 mph, a feat some refused to believe. This record stood for five years until it was broken by an automobile.

Curtiss' expertise with engines eventually caught the attention of Alexander Graham Bell, inventor of the telephone and an aviation enthusiast himself. Bell recruited the young man for the Aerial Experiment Association, a group of five men whose aim was to get off the ground with a powerful, heavier-than-air machine.

Within two short years, the AEA not only got off the ground but also extended and developed the principles established by the Wrights. The AEA's secret was Curtiss' use of ailerons, which permitted better control and a stronger wing structure than the Wrights' wing-warping scheme allowed. (It was also a development that resulted in years of patent infringement lawsuits by the Wrights.) Curtiss was the star of the group, and by 1909 he was building airplanes in his motorcycle plant.

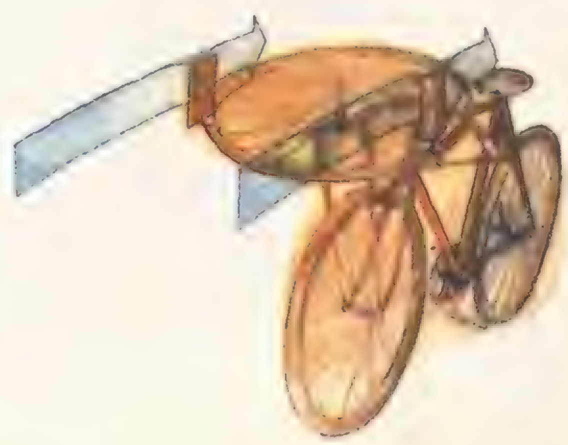
All around the world, bicyclists were making the move to airplanes. In France, Henri Farman had been a solo bicycle champion, and he and his brother Maurice made up a world-class tandem bicycle team. They also raced motorcycles and automobiles. In 1908 Henri won a 50,000-franc prize by taking his Voisin biplane on the first closed-circuit flight in Europe. He and Maurice later built their own aircraft and established one of the first airplane factories in France.

NASM

The Wright Cycle Company (above) provided Wilbur and Orville with time, money, and a crude method of testing airfoils (below).

In Germany, August Euler, the country's father of aviation, established the first German airplane plant and was awarded the nation's first pilot's license. In 1895 he had won the grueling Cologne-Sinzig-Cologne bicycle race. Germany's second pilot's license went to Hans Grade, another bicycle racer.

Cycle racer Hélène Dutrieu of Belgium was one of the first women to fly in Europe. Some of her cycling exploits were startling. Using a special board track, she became the only woman to perform the dangerous bicycle loop-the-loop. To make it even more dangerous, she did it with the top section of the loop



NASM

The wheels on Cayley's gliders were ancestors of those on Curtiss racers and Blériot airplanes (below).

removed, a stunt that had crippled or killed men who had tried it before.

Alessandro Anzani was a professional Italian bicycle sprint champion who became the king of European motorcycle-bicycle pacers. Like Glenn Curtiss he built his own light powerful engines. It was Anzani, by then a French citizen, who constructed the engine that powered Louis Blériot's monoplane on the first powered flight across the English Channel in 1909.

Even Otto Lilienthal, who died in a glider crash in 1896, had had ties to cycling. He and his brother once built passenger-carrying tricycles and made long-distance trips near Berlin before the invention of the modern bicycle.

Perhaps one reason so many bicyclists made the transition to flight was because bicycles and airplanes share a number of control difficulties. In 1896 James Howard Means of Boston wrote in his *Aeronautical Annual* that "[t]o learn to wheel one must learn to balance; to learn to fly one must learn to balance." Tom Crouch of the aeronautics department of the National Air and Space Museum notes that the process of turning an airplane or a bicycle is nearly the same: you must lean or bank into a turn to counteract centrifugal force. In the case of the bicycle, the tire and road

Henri and Maurice Farman had been bicyclists. By 1910 their airplanes were taking wing over France.

friction provide the cornering force; for an airplane, banking gives an inward lift force that keeps the airplane from skidding into a turn.

Anyone learning to fly an airplane or ride a bicycle must practice a great deal until his reactions become automatic. Bicycles and airplanes are stable only for a few moments at a time, and both require constant corrections to compensate for minute disturbances from the air or the road in order to maintain equilibrium. Pilots and cyclists must have excellent reflexes and a sense of balance and orientation in space.

Early airplanes were much less stable and more difficult to fly than today's craft. Veteran bike racer Jack Lambie is in a position to know: he has flown replicas of Lilienthal's glider, the Wrights' gliders, and two Wright Flyers. He also flew a reproduction of a 1911 Curtiss flier and a hang glider based on an 1896 design of French-American flight experimenter Octave Chanute.

Of the 1903 Wright Flyer, Lambie says, "It was absolutely unstable. It porpoised through the air and was very sluggish to react. I don't know how they flew it. Before trying to fly it I practiced by balancing it on a log facing into the wind on the beach near Santa Barbara. It took hours before I could come close to controlling the beast. It was like rubbing your stomach and patting your head while trying to cross a tightrope on a unicycle." Lambie has an only slightly better opinion of the Curtiss flier, a replica of which his brother crashed and destroyed in 1978.

Aside from their riders and pilots, cycling and early aviation shared a critical need for strong yet light structures. Excess weight is anathema to both airplanes and bicycles. Saving weight has always been a virtual religion with bike racers, who will spend hundreds of dollars to remove a single pound from a bicycle. The ultralight diamond frame of a typical expensive racing bicycle of the 1890s was built from high-strength thin-wall tubing and weighed about six pounds. It could carry over 30 times its weight for thousands of miles over jarring rough roads.

Most early airplanes were little more than light, rigid frames constructed of tubing in accordance with the same principles used in constructing bicycles. The first wide use of brazing and electric welding, often employed in building early aircraft, was in the manufacture of bicycles. The Wright brothers even utilized strong spoke wire to guy the wings of their first Flyers. Other shared technologies include the sprockets and roller chains, familiar to cyclists everywhere, that drove the propellers of the first Wright Flyer. Ball bearings, originally invented for agricultural machinery, were perfected and first used in large numbers in bicycles before being employed in flying machines.

Likewise, the wheels and tires of early aircraft were first seen in similar form on bicycles. Although the Wrights used skids for the landing gear of their first Flyers, almost everyone else preferred light tension-spoked wheels with pneumatic tires. This type of wheel is attributed to Sir George Cayley, builder of the first successful passenger-carrying gliders in the early 1800s. The wheel was later changed and improved on bicycles; crossed instead of radial spoking was employed to allow high torques to be applied without deforming the wheel.

Further, the modern pneumatic tire

In 1878 Charles Ritchell was using pedal power to propel his early single-seat dirigible (left).

When Louis Blériot crossed the Channel he used an engine built by motorcyclist Alessandro Anzani.

NASM (2)

was developed for the bicycle. In 1888 John Boyd Dunlop, a veterinarian living in Belfast, patented and began manufacturing a pneumatic tire he had made for his son's tricycle. By 1891 nearly 40 percent of the bicycles in England used pneumatic tires.

Another factor common to bicycles and airplanes is the importance of the wind. Airplanes, of course, need air to provide lift and control, but they also function best when streamlined to minimize wind resistance. Any unnecessary air drag means a loss in speed and increased fuel consumption. The same is true for bicycles: even in still air, wind resistance is the major force acting against a bicyclist at speeds over 10 mph. For a cyclist traveling in excess of 18 mph on level ground, wind accounts for over 80 percent of the retarding force (the other 20 percent being due to the friction of the tires and bearings).

CHESTER KYLE (3)

Streamlining became increasingly important as bicyclists sought higher and higher speeds. Etienne Bunau-Varilla's 1913 Vello Torpille used streamlining techniques that would only later be echoed in airplanes.

Record-setting bicycles today employ a number of streamlining techniques. In 1974 author Chester Kyle's streamliner set records in California (top). The Tachy Taxi, powered by both hand and feet cranks, looks more like a wheeled torpedo than a bicycle (above left). Even relatively conventional bikes, like that used by Steve Hegy in the 1974 Olympics (above right), use streamlining discs on the wheels.

Long before 1900, cyclists realized the importance of minimizing wind resistance and adopted dropped handlebars and an uncomfortable crouched racing position to give the body a more streamlined shape. About 1890, cyclists in Europe found a way to lessen air resistance while setting speed records. Because a multi-seat bicycle pedalled by three or more riders could go much faster than a bike with a single rider, record-setting cyclists would ride behind such "air plows" to obtain faster speeds. It quickly became popular to set point-to-point and track records with enormous four- to six-man bicycles providing protection from the wind for the record setter. Before long, these huge multiple-seat pacers were being re-

Perhaps the ultimate hybrid of bicycle and airplane, Daedalus *crossed the Sea of Crete in 1988, powered by a bicyclist.*

CHUCK O'REAR/WESTLIGHT

placed by the first motorcycles.

But even with motorcycles, bicycle pacing was a cumbersome way of reducing wind resistance, so cyclists explored other reduction techniques. In his 1896 book *Bicycles and Tricycles,* British engineering professor Archibald Sharp included an illustration of a bicycle with a solid disk wheel. "It was claimed—" Sharp wrote, "and there seems nothing improbable in the claim—that the air resistance of these wheels was less than that of wheels with wire spokes." The solid disk was nothing more than a streamlined wheel, something that wasn't commonly installed on airplanes until World War I.

In 1913, Etienne Bunau-Varilla of France obtained European and American patents on a completely enclosed, fully streamlined bicycle he called the "Vello Torpille," or Flying Torpedo. A pair of these swift machines, resembling mini-dirigibles on wheels, raced in Berlin in 1914. The bicycles employed streamlining designs that were much more sophisticated than the airplanes of 1914, which still looked like frail constructs held together by wire and spruce. Completely enclosed fuselages were not widely used in airplanes until after World War I.

In 1948, during his last flight, Orville Wright briefly took the controls of a four-engine Constellation. By then both Wright and the airplane had left their bicycling days far behind. Yet in some quarters the relationship between bicycles and airplanes continues today. In 1986, *Goldrush,* a bicycle ridden by Fred Markham, won the $18,000 Dupont prize, awarded for unassisted human-powered vehicles, by reaching a speed of 65.48 mph near Mono Lake, California. The fully enclosed, streamlined bicycle had been designed by Gardner Martin in accordance with aerodynamic theory. And on April 23, 1988, an aircraft named *Daedalus* made a 74-mile trip over the Sea of Crete. The craft was powered by the pedalling of cyclist Kanello Kanellopoulos. Technology, it seems, has made a full circle.

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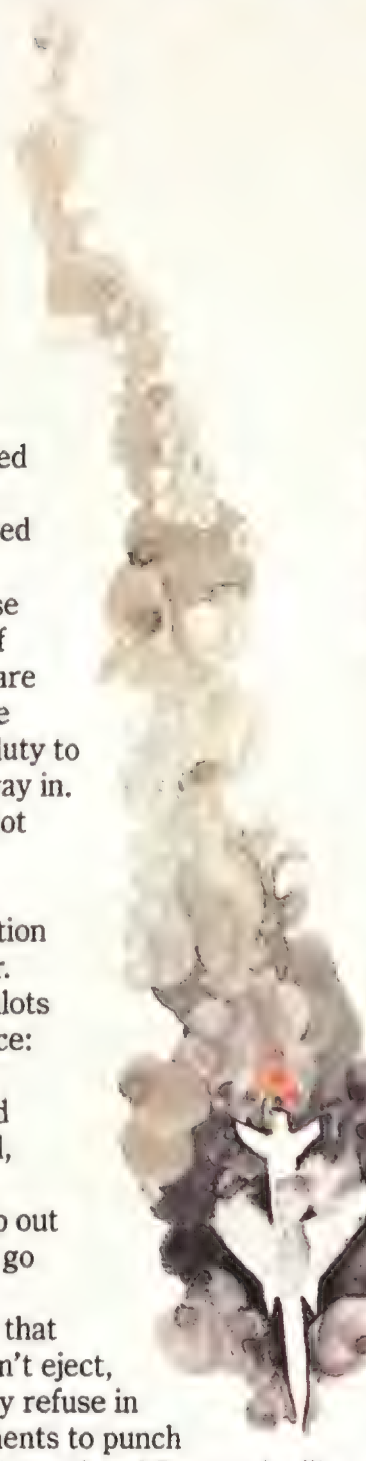
Groundling's Notebook



MICHAEL DAVID BROWN

On Impact

In the late 1970s I lived in Southern California. The house was small, set on a tiny lot out where the road ended at one of those black-and-white wooden barriers. If I got up early enough, I'd see deer in the meadow out back.

One morning I was looking out the kitchen window, sleepy-eyed, sipping coffee. There was usually a nice view of some grassy hills and the Pacific Ocean, but the ocean air had rolled in overnight, and the fog had lifted only enough to allow a glimpse of the first row of hills to the southwest. Then the morning stillness was nudged by a whisper, like the sound of a sigh, followed by a thump. An airplane had crashed.

Some of the details have faded since then, but what astonishes me still is that in an instant I knew I'd heard an airplane come down at high speed. There have been so many sounds like it—bumps in the night, distant thunder, the cats knocking over a book—yet in that instant, I knew.

I rose, and said aloud, "That was an airplane." I remember saying it in a matter-of-fact way, as if announcing to no one in particular that the mail had arrived. It wasn't until months later that I wondered about how I had known so suddenly and with such certainty.

I turned on the news, of course, and within an hour or so the first bulletin was broadcast about an Air Force fighter that had crashed near Camarillo, about 10 miles to the west. Later I learned that the pilot had gone down with it. Within a day or two a short item appeared in the *Los Angeles Times*—pilot's name, unit, aircraft type, investigation, no details yet.

I tried to reconstruct the sound in my mind—the whistle of the air, the little shock wave that had rattled the window so slightly, and the thump of the impact that had traveled through the ground, up through the slab beneath the house, through the kitchen floor, and into the soles of my feet. It was no more than the sound a falling stone might make, but to me it had the finality of a farewell.

Some pilots—heroes—are said to have stayed with their stricken aircraft to avoid hitting populated areas, but I've always wondered how people determine these things. It's as if military pilots are thought to have some implicit duty to ride it all the way in. Whenever a pilot bails out and survives, an unspoken question hangs in the air. Most civilian pilots have little choice: few wear parachutes, and even if they did, airplanes are difficult to jump out of when things go wrong.

It's also said that some pilots won't eject, that they simply refuse in their final moments to punch out. Who can blame them? It must be like leaving the family hearth to run outside, head off to a cliff, and leap into a freezing lake. The embrace of the airplane would be overwhelming. I've never flown jet fighters, but I'd felt the awful panic of discovering that I'd flown into a thunderstorm. I'd passed through unharmed, landed in a golden sunset, and trudged home humbled but alive. But what of this pilot? What fears seduced him, drove him to work overtime?

His fighter—a Republic F-105—was an old airplane when it crashed. The paper noted that it had been years since the last one was built, and I was surprised when I heard the type—you hardly ever saw them around anymore. Its panel would have been worn down to the metal where hundreds of gloved fingers had turned a knob and polished the corner of a bezel. There'd be dust and grime under the cockpit floor, pencils, paper clips—the stuff found in old-dog airplanes that have had a couple of decades' worth of masters. The glareshield would have been pockmarked with dings from clipboards and helmets, and the metal parts of the control stick would be etched by sweat. Like any high-performance jet fighter, it would have had the explosive nervousness of a young racehorse when it was new—military jets seem like barely constrained bombs—but it would have become cranky with age.

I imagined the last minute or so when things began to go wrong for its pilot. The whisper I'd heard before the impact was the rush of the airplane falling through the atmosphere. There'd been no engine noise. So he'd had a flame-out, I guessed. In a single-engine jet, that means you point the nose almost straight down in an attempt to maintain control. And of course all the warning systems would have been triggered, buzzers and horns sounding their inarticulate complaints.

The fog was probably just a low cloud deck with clear sky above it, typical of a California morning. So he'd have started that final dive up in the sunrise, looking down at the blank cotton that hid the hard ground. And in the end he must have had a moment, just a flash perhaps, when he realized he'd lost it. All the confidence his training gave him, his trust in himself and the Air Force, his faith in his crew chief—all of that would have driven him to try to win, to try to bring the airplane down in the same shape in which he'd taken it up.

Maybe he hated the thing. Maybe it had been written up a hundred times for the same failures. Maybe it was the one airplane in every unit that never seems to work quite right. No matter, though. When things went wrong he'd have tried everything to save it.

Random, remote violence does have its fascinations. For as long as I can remember I've been drawn to the window during thunderstorms. I try to imagine where the bolts are striking. And when I hear a report of an airplane crash, I wonder what it was like to be inside it. But I never heard and felt the impact of a falling airplane before or since that one, and it is something I will always remember.

—*George C. Larson*

APOLLO 11 20th ANNIVERSARY
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Autographed By
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The Sound of Wings: The Life of Amelia Earhart *by Mary S. Lovell. St. Martin's Press, 1989. 420 pp., b&w photos, $22.95 (hardbound).*

Mary S. Lovell's *The Sound of Wings: The Life of Amelia Earhart* is really two separate but interwoven biographies. One, of course, is the story of the famed aviatrix, made even more famous by her disappearance over the Pacific while on a round-the-world flight in 1937; the other is the story of publisher George Palmer Putnam, her publicist and later her husband.

Lovell, author of the Beryl Markham biography *Straight on Till Morning,* has a sound reason for choosing such a format: had Putnam not entered Earhart's life, books such as this probably would not exist. The acclaim Earhart earned for her series of record-breaking flights reflected Putnam's prodigious abilities as a publicist almost as much as her skill as a pilot. Putnam was adept at keeping Earhart's name before the public—so much so that it is a common belief among many of her biographers that their marriage was merely a convenient business arrangement.

Lovell convincingly argues the opposite view: that Earhart and Putnam's marriage, despite her fierce independence and his relentless marketing of her exploits, was a happy, full, and satisfying one. Far from being exploited, in fact, Earhart seems to have blossomed in the role Putnam created for her, going on to become every bit the heroine he fashioned her.

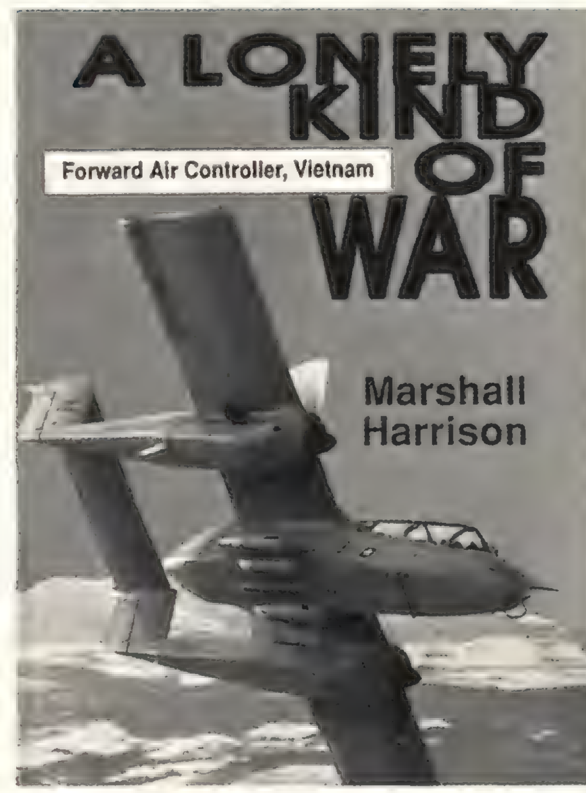
That the woman who emerges from Lovell's portrait is also immensely likeable makes the carefully detailed account of her final flight all the more painful. There have been many intriguing theories about Earhart's disappearance, but Lovell's explanation places the blame on the sheer exhaustion of the pilot and her navigator, and on Earhart's inept handling of the airplane's radio.

Following Earhart's departure from the story, Lovell's dual-biography approach weakens the book as she goes on to chronicle Putnam's two subsequent marriages, further business ventures, and squabbles with Earhart's relatives over money. By the book's end, Earhart is a distant figure. Overall, though, *The Sound of Wings* presents a deft portrait of its intelligent, willful subject—a young woman forever cloaked in the allure of her mysterious disappearance.

—Karen Jensen is an associate editor of Air & Space/Smithsonian.

A Lonely Kind of War *by Marshall Harrison. Presidio, 1989. 285 pp., $18.95 (hardbound).*

Marshall Harrison is a Texan and a retired Air Force forward air controller who narrates his experiences directing airstrikes in Vietnam. I mention his being a Texan because it might help to explain the tone of this book: Harrison apparently recreates a lot of dialogue from memory, and the writing takes on the quality of a tall war story. You don't question the basic truth of what he writes; what you do



question is his sense of dimension. And if American combatants in Southeast Asia were really as witty as Harrison depicts them, it should be quite a while before we experience a shortage of television writers.

The details of how a forward air controller operates are fascinating as they unfold but become somewhat repetitious: by the fourth airstrike we know the radio procedure for checking in with a flight leader almost too well. Harrison also delves into the internal culture of the Air Force, and he's captured the deep-rooted cynicism line troops felt toward their command and fashioned it into a verity that will make some readers squirm.

Harrison doesn't go out of his way to depict himself as a hero, and by the end of the book I found I didn't like him a whole lot. But it's also pretty clear that he doesn't care what anyone thinks, and his honesty more than compensates for his modest talents as a writer. Don't expect any apologies, either. Harrison's job was to kill the enemy, and he doesn't shrink from describing precisely how he did it.

—George C. Larson is the editor of Air & Space/Smithsonian.

***Merlin's Tour of the Universe** by Neil De Grasse Tyson. Columbia University Press, 1989. 300 pp., line drawings, $29.95 (hardbound).*

"Time is defined to make motion look simple."

This glib response to the question "What is time?" is typical of this breezy little volume. Based on a question-and-answer column in *Star Date*, the McDonald Observatory's popular astronomy magazine, *Merlin's Tour of the Universe* consists almost entirely of brief, usually humorous, mostly accurate, and sometimes profound responses—the one quoted above is by none other than Albert Einstein—to queries from readers aged four to 90. I am sure the questions are legitimate, since I have encountered most of them myself in three decades of planetarium work.

The "Merlin" of the title, a fictional visitor from the Andromeda galaxy, is the alter ego author Neil De Grasse Tyson adopts to answer them. The book is organized into 13 chapters, each dealing with a particular aspect of astronomy more or less ordered by increasing distance from Earth, and each introduced by a page or two of very basic description of the phenomena to be treated. While the book makes no pretense of being an astronomy text or even a comprehensive reference for the layman, I suspect that many people with a casual interest in things celestial will enjoy browsing through it to find a stimulating item or two for cocktail party conversation.

What makes this tiny tome so much fun are the answers. There are occasional one-word zingers: to a verbose question as to whether a resident of a planet with two suns would have two shadows, Merlin's response is "Yes." The longest answers are about a page in length and seem to be triggered when a questioner happens upon one of the author's favorite topics or pet peeves, such as relativity, tachyons, and the endangered ozone layer.

There are a few instances, though, in which Merlin seems to misinterpret his reader's questions. For example, someone poses the (admittedly awkwardly phrased) question "Why is it that when you leave the atmosphere it is cold, but coming back it is hot?" It seems to me the question pertains to the heating up of spacecraft upon reentry, but Merlin responds with half a page about spacesuits. In another case, the author sacrifices accuracy to brevity when he states flatly that the precession cycle of Earth—the slow change in the orientation of its axis—has no effect on the weather. Some atmospheric physicists believe that this cycle at least contributes to—and perhaps even causes—the recurrence of ice ages in the northern hemisphere.

An informative glossary and bibliography round out the book, helping to make *Merlin's Tour of the Universe* a trip well worth taking.

—James H. Sharp is the National Air and Space Museum's planetarium director.

***Milestones of Aviation: Smithsonian Institution National Air and Space Museum,** edited by John T. Greenwood. Hugh Lauter Levin Associates, Inc., 1989. 310 pp., b&w and color photos, $75 (hardbound).*

Rather than simply documenting the National Air and Space Museum's aviation collection, this ambitious coffee-table book packages it in the broader context of world aviation history. An excellent selection of illustrations, including some lovely hand-tinted historical photos and dramatic contemporary shots, makes up for a lackluster text.

***Japanese Naval Aces and Fighter Units in World War II** by Ikuhiko Hata and Yasuho Izawa. Naval Institute Press, 1989. 433 pp., b&w illustrations, $46.95 (hardbound).*

Nearly half a century after the Japanese Navy Air Force devastated the U.S. fleet at Pearl Harbor, Americans still know almost nothing about the men responsible for that astonishing feat. Now here is a magnificent volume to explain what we should have known in the first week of December 1941: that Japan, and especially the Japanese Navy, boasted some of the finest fighter pilots in the world, blooded in four years of combat in China and possessed of a bravery that was literally suicidal. They also had a nimble and deadly aircraft, the Mitsubishi A6M Zero, but this book deals only in passing with hardware. Rather, it offers a capsule history of each JNAF fighter squadron that saw combat between 1937 and 1945, and short biographies of the squadrons' leading pilots.

Ikuhiko Hata is a respected historian; Yasuho Izawa is a physician and aviation writer. To compile this book, they scoured Japanese records and interviewed survivors—no easy feat, because the concept of an "ace" is alien to Japanese culture and individual pilots' records were not kept. In addition, there weren't many survivors, and the aircraft of several squadrons were destroyed in 1944-1945; the pilots became foot soldiers, and no one bothered to preserve the squadron logs.

As a result, the biographies are largely based on anecdote and include the exaggerations of hearsay. Hiroyoski Nishizawa is credited with shooting down 87 U.S. aircraft, and more than 100 JNAF

pilots supposedly shot down 10 or more enemy airplanes each, an achievement that would have earned them the status of double ace outside Japan. The numbers are incredible, as the authors tacitly concede in an appendix that compares Allied and Japanese claims for various battles.

What cannot be argued, however, is the price these men paid for their devotion to the emperor. All nine naval officers who became fighter pilots in September 1939 were killed in action; of 21 enlisted fighter pilots who earned their wings in September 1941, only one survived the war.

Historians will find the book most useful for the unit histories that fill more than half its pages, and for its several detailed appendices. Here is the information against which to test the combat claims of Allied pilots—themselves, it would seem, somewhat exaggerated. Some Allied air triumphs turn out to have been celebrated as victories by Japan as well, especially in the days before gun cameras were installed on U.S. airplanes. (That Japanese pilots did not film their combat no doubt likewise boosted the scores here attributed to them.) Thus, on the emperor's birthday in 1938, JNAF airplanes battled Chinese and Soviet fighters over Hankou. The defenders claimed 24 Japanese airplanes shot down; the reality was four. The Japanese airmen were equally vainglorious, claiming they had downed 51 fighters when in fact nine were destroyed or forced down. (That last figure is mine, based on Chinese records.)

Not everyone will share my interest in such details, but this book is worth reading if only for its insights into the Japanese fascination with war and death. In an unintentionally chilling foreword, translator Don Cyril Gorham notes that the original text of the book contains nine different Japanese words relating to death in battle, five of which refer to varieties of self-destruction. Time and again, we are told that a ship, a squadron, or a pilot "was not favored by the gods of war"—that is, denied the opportunity for combat. I cannot imagine an American writer using that image today, or writing an elegy like this one, for Petty Officer Kiyoshi Shimizu:

"Shimizu's air combat life was a matter of a few months spent at Rabaul. He appeared to project irresistible force, however; in a mere twenty some days following his first shoot-down of an enemy plane on 4 January 1944, he flamed twelve enemy aircraft . . . . Shimizu was to fall as the cherry blossoms fall."

—Daniel Ford is writing a history of the American Volunteer Group—the "Flying Tigers"—who defended Burma and China in the winter of 1941-1942.

Credits

45 More Missions. Jack Keil is a writer, actor, and ex-advertising man. He is the creator and voice of the National Crime Prevention Council's spokesman, McGruff, the Crime Dog.

It Came From the U.S.S.R. Alex Heard is a Washington, D.C. writer.

The Zero: One Step Beyond. Steven L. Thompson is a pilot and the author of numerous works in the aviation and motor sports fields.

Further reading: *Eagles of Mitsubishi: The Story of the Zero Fighter,* Jiro Horikoshi, University of Washington Press, 1981.

Zero Fighter, R. Mikesh, Crown, 1980.

Ticket to Ride and Ride and Ride. . . . Photographer Mark S. Wexler can't get enough of being at 30,000 feet. He travels the world for such publications as *Time, Life, National Geographic,* and *Smithsonian.*

The Rescue of Salyut 7. Saunders B. Kramer is an expert on the Soviet space program.

Higher Learning. An editor at Time-Life Books, Carl A. Posey is a frequent contributor to *Air & Space/Smithsonian.*

Invasion of the Spacebots. Greg Freiherr is a contributing editor of *Air & Space/Smithsonian.*

Venus on a Shoestring. Geologist Don Wilhelms worked with the U.S. Geological Survey in Menlo Park, California, from 1962 until 1986, mapping and interpreting the moon, Mars, and Ganymede.

Further reading: "Venus Unveiled," S.D. Wall, *Astronomy,* April 1989.

"Voyage to Venus," Robert Kunzig, *Discover,* April 1989.

"The Planet Next Door," A.T. Bazilevskiy, *Sky and Telescope,* April 1989.

The Bicycle-Airplane Connection. A cycling researcher and sports equipment consultant, Chester Kyle is the science editor of *Bicycling Magazine.* He designed the bicycles and clothing for the 1984 U.S. Olympic cycling team.

Wolfgang Gronen, a cycling historian, is a former bicycle racing team manager who trained several world and Olympic champions.

On Impact. George C. Larson is the editor of *Air & Space/Smithsonian.*

"The Satellite Sky" Update/16

These regular updates to **"The Satellite Sky"** chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

New launches

90 to 300 MILES

- Cosmos 2048 10-89 PL
- Cosmos 2049 11-89 TT
- Cosmos 2051 11-89 TT
- Kvant 2 11-89 TT
- Cosmos 2052 11-89 PL

300 to 630 MILES

- COBE 11-89 VAFB

630 to 1,250 MILES

- Meteor 3-3 10-89 PL

6,200 to 13,700 MILES

- GPS-4 10-89 CAC

21,750 to 22,370 MILES

- Intelsat 6 F-2 10-89 KOU

Launched but not in orbit

90 to 300 MILES

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STS-33 USA research	11-23-89	down 11-28-89

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But it seemed to me some fine-tuning could be done with a flying model. I've been building and flying model airplanes since about the second grade and figured we could do the same thing with missiles.

So I got busy in the basement and started drawing up a quarter-scale version of the one we were working on. It cost maybe $100 to build it and fly it on top of one of my model planes.

This way we were able to verify its flight dynamics early, long before we made the major investment of time and money in a full-size missile.

It might be hard for some people to see how a hobby like mine could have practical application. But fortunately, I work with people who have vision, people who latch on to a good idea fast—without too much fuss about where it comes from."

—Dave Abel, Missile Systems, Logistics Engineer

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